Weatherwise

PROPOSED CHARLES FRANKLIN BROOKS
MEMORIAL OBSERVATION TOWER

Volume 12, Number 4 August 1959

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

Proposed Tower at Mount Washington

Architects' Report

THE program of requirements for this project has been developed by this office and reviewed by various interested parties of the Observatory and its staff. The design required the following major elements:

1. An open deck elevated at least twenty feet above the ridge of the present Tip-Top House.
2. A closed laboratory area, unheated, for cold weather instrumentation and analysis.
3. A closed laboratory area, heated, for work during cold weather.
4. An observation area available to the summer tourists, particularly those who use the Cog Railway.

In solving these requirements, a design was developed using an inverted conical shape. This shape was employed to avoid all possible turbulence in the area of the open deck and the cold laboratory. Below the laboratory area a circular public observation gallery has been provided. To meet the warm laboratory requirements, we feel that the southwest corner room on the upper floor of the Tip-Top House is best suited, with heat being supplied by electric heaters or a small warm air furnace not connected with the main heating or lighting systems of the House.

Access to the Tower for the public as well as for observatory personnel is provided principally from the second floor of the Tip-Top House.

In order to provide a second means of egress from the second floor and eliminate all possible cross traffic to and from the Tower, the central stairway spirals down to grade with a door to the outside.

In a separate report written to Dr. Brooks of the Mt. Washington Observatory, we outlined a suggested use of the Tip-Top House as an active museum of science and history for the mountain top. The proposed Tower and the use of space by the Observatory are integrated into this particular long range approach.

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Front Cover: An artist's sketch of the proposed Charles Franklin Brooks Memorial Observation Tower at Mount Washington, New Hampshire.

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LOCATION OF NORTHERN HEMISPHERE
SURFACE WEATHER REPORTS

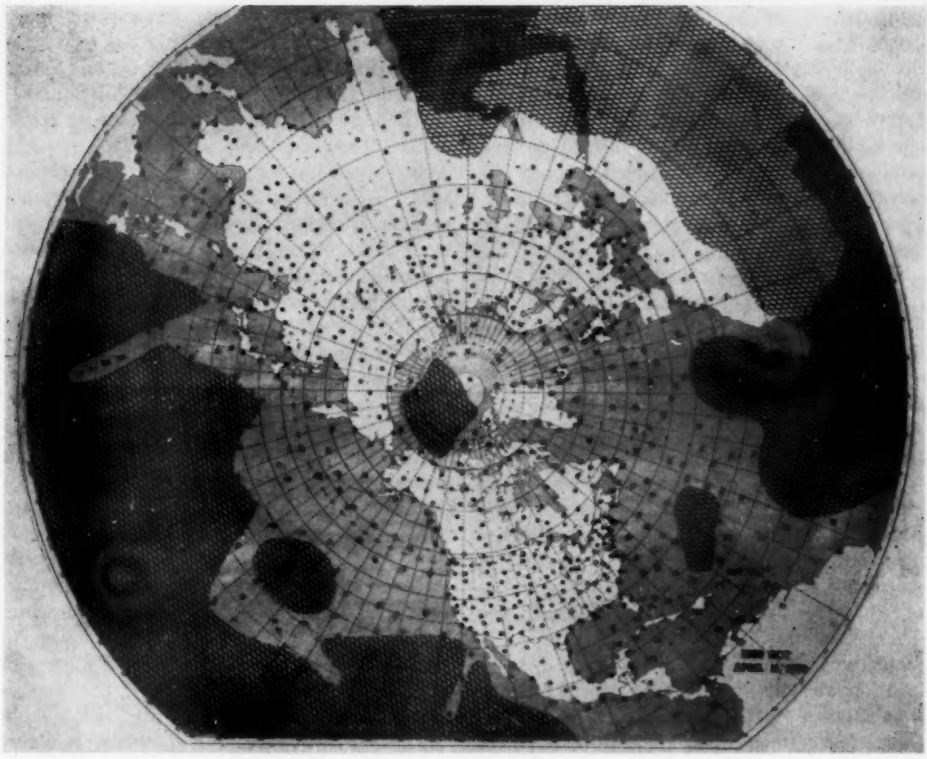


FIG. 1. Northern Hemisphere map of station reports received operationally. The density of reporting stations in the United States is greater than shown in the figure.

On Observing the Atmosphere from Satellites— I. Cloud Observations[1]

SIGMUND FRITZ, *U. S. Weather Bureau, Washington, D. C.*

FOR many scientific disciplines the artificial satellite represents a new observing platform from which new facts can be learned about our Universe; and for meteorology, in particular, satellites provide platforms from which, in principle, every point on the Earth's surface and in the Earth's atmosphere can be observed with suitable instruments. Certainly satellites will, as a minimum, permit us to view the whole Earth in all horizontal directions from a vantage point well above the "lower" atmosphere. This new observing platform will furnish us *new basic data,* some of which will have operational value in the near future.

All meteorological observations of the "lower" atmosphere which have so far been suggested depend on some type of radiation

[1] This work has been supported by the National Aeronautics and Space Administration.

measurement; e.g., solar radiation reflected by the planet, infra-red energy emitted by the planet, or energy in the radar-radio spectrum emitted from the satellite, from the ground or from the atmosphere. The observation of clouds in daytime is an example of such a measurement involving the sensing of solar radiation reflected by clouds, by the atmosphere, and by the Earth's surface to the satellite. This paper considers cloud observations only; in a later paper other atmospheric measurements from satellites will be discussed.

The observation of clouds involves *at least* three types of information. First we can measure cloud amount; secondly, we will often be able to determine cloud type; and third, we can observe cloud patterns such as vortices, cloud "streets," frontal cloud fields, etc. Features such as vertical shear can sometimes also be determined. In regions from which cloud observations are not now available, the satellite will obviously supply new data (1–5). But even in dense meteorological networks, satellites will reveal cloud patterns which are not observable from the ground at present.

Consider first the world-wide density of meteorological stations. Figure 1 shows the location of synoptic weather reports received for the entire Northern Hemisphere in the National Meteorological Center of the Weather Bureau (NMC) for 1200 GCT, 11 April 1959. Some additional information is available from airplane weather reconnaissance flights, and from continuity with earlier weather maps. If one waited for "historical" data, there would doubtless be additional reports, especially over certain land areas. But as an operational matter, figure 1 represents the present state of affairs for the Northern Hemisphere, with its vast areas from which no reports are received. Some data-sparse regions are indicated by the shaded areas such as the one covering most of the Pacific Ocean south of latitude 20°N. Even in those Pacific Ocean areas where the coverage is better, large areas occur with few or no reports. For example, Area A, north of the Hawaiian Islands, is a region of about 800 miles in diameter with no reports on this map. Similar regions occur in the Atlantic, the Arctic, and other ocean areas as well as over several continents. Of course, over most of the Southern Hemisphere, the station density is much sparser than it is over the Northern Hemisphere (6).

From the oceanic station network of figure 1, we can expect to obtain only the very large scale cloud-amount information. Even in the "denser" reporting oceanic areas of figure 1, the reports are usually 150 miles or more apart. Thus only large scale cyclonic systems whose overcast patterns cover hundreds of miles in diameter can be detected in those regions. Cloud systems with diameters smaller than 100–200 miles cannot be directly observed, but must be inferred if possible from other observations; and this is often difficult to do. In the less dense reporting areas, even cloud-amount on the scale of cyclonic systems will not be adequately represented. Thus it is clear that satellite observations will improve the *cloud amount* data in many oceanic areas; and for operational use in NMC, improvement will also occur over many land areas such as Africa and southwestern Asia, to the extent that cloud information can be used in map analyses.

Cloud *type* is also observed from the surface stations. Obviously satellite observations will also improve the geographic coverage of *cloud type* data much as indicated above for cloud amount data. Moreover, the surface stations observe cloud types from below looking up; satellites will add to this by yielding information about cloud types as seen from above although questions of subjective interpretation will arise, as they often do now from surface observations.

Finally, we come to the cloud *patterns* which exist in the atmosphere. Among the most striking patterns are the vortices. And there seems good reason to expect that vortices occur fairly frequently in the atmosphere. Consider for example photographs taken from rockets. Such observations are rather few in number and are usually taken during times of good weather, since the pictures are mainly needed for other purposes. Yet, in spite of that, quite by accident, the striking upper-air "Texas" vortex of figure 2 (a) was photographed during a rocket experiment (7). How common are vortices such as this one, with dimensions of a few hundred miles in diameter? The answer is not known, for *it is impossible* to observe the vortex cloud *pattern* from the ground with

present cloud reporting techniques even in the densest possible network. And in networks that actually do exist in the Central United States, with adjacent, hourly cloud reporting stations often more than 50 miles apart, it would be impossible to observe the cloud *pattern* from the surface with *any* visual or photographic technique.

That this is true can be seen from the following considerations. An observer who looks at the cloudy sky cannot see any cloud pattern detail near the horizon because cloud spaces and features are hidden by the vertical structure of the clouds themselves. The particular angular elevation above the horizon at which this occurs will depend on the particular dimensions of the cloud field; in some cases it may be 10°, in others it may be 20° or more. Let us assume that cloud features in a broken or overcast sky can be clearly seen only for elevation angles greater than 20° above the horizon. Then Table I shows approximately the horizontal distance, *d*, from the observer's zenith to which cloud detail can be seen. In Table I, *"h"* is the height of the cloud base.

TABLE I

DISTANCE (MILES) TO WHICH CLOUD PATTERNS CAN BE SEEN FROM GROUND OBSERVATIONS

h (mi)	.2	1	2	4	6
d (mi)	.5	2.7	5.5	11	17

For a cloud whose base is 2 miles high (about 10,000 feet), an observer could distinguish patterns clearly for only about 5–6 miles in all directions. Thus merely to *see* the whole cloud pattern, observers would have to be about 10 to 12 miles from each other. Even then, it would not be sufficient to report the cloud amount and/or cloud type. It would be necessary to describe the orientation and characteristics of all cloud features, as for example, with a photograph; and then one would have to collect all the photographs into a mosaic. This is a practical impossibility, and therefore the frequency of occurrence of cloud vortices is not known even in dense networks. In cases where appreciable precipitation is occurring, radar would be helpful in extending the observer's horizon. But when precipitation is absent or too light, or when no radars are available in an area, then the satellite, from which hundreds of miles in all directions can be viewed, is a suitable platform from which to observe the cloud patterns—the regular observations of cloud patterns hardly ever observed before will soon become a reality.

The cloud vortex is merely one feature; the hurricane is an outstanding example of the type of storm which can be revealed and tracked from vortex observations. Figure 2 also contains examples of cloud "streets" in which cumulus clouds are arrayed in lines. Often these lines are oriented with the wind direction; sometimes they are not. Further research is needed to delineate those situations when the cumuli do align with the wind; then, this type of observation will be a valuable wind direction indicator in oceanic, and other data-sparse regions. Orographic clouds may indicate wind flow near mountains; bands of overcast clouds are often associated with frontal systems—these and other synoptic features of the atmosphere will be inferred from cloud pictures. For climatology, world-wide cloud pictures can provide a truly global estimate of the average distribution of cloud amount.

PRESENT STATUS—SATELLITE CLOUD OBSERVING PROGRAMS

To obtain the new cloud information outlined above, several programs are in various states of completion; others are still in the "talking" stage. Cloud observations by photocells, television cameras, and other spectral instruments have been or will soon be attempted.

1. Photocells—Vanguard II

Vanguard II, launched on 17 February 1959, was the first satellite placed into orbit which carried instruments designed to measure cloud distribution (8,9). The experiment, designed by the Army Signal Research and Development Laboratories, attempted to observe cloud distributions by "looking" at the Earth with two photocells; the electrical output of the cells was recorded on magnetic tape and the stored information was transmitted to the ground at command from "readout" stations, when the satellite was above the horizon at these stations. The batteries were designed to last for about two weeks so the cloud signals ended on 7 March 1959

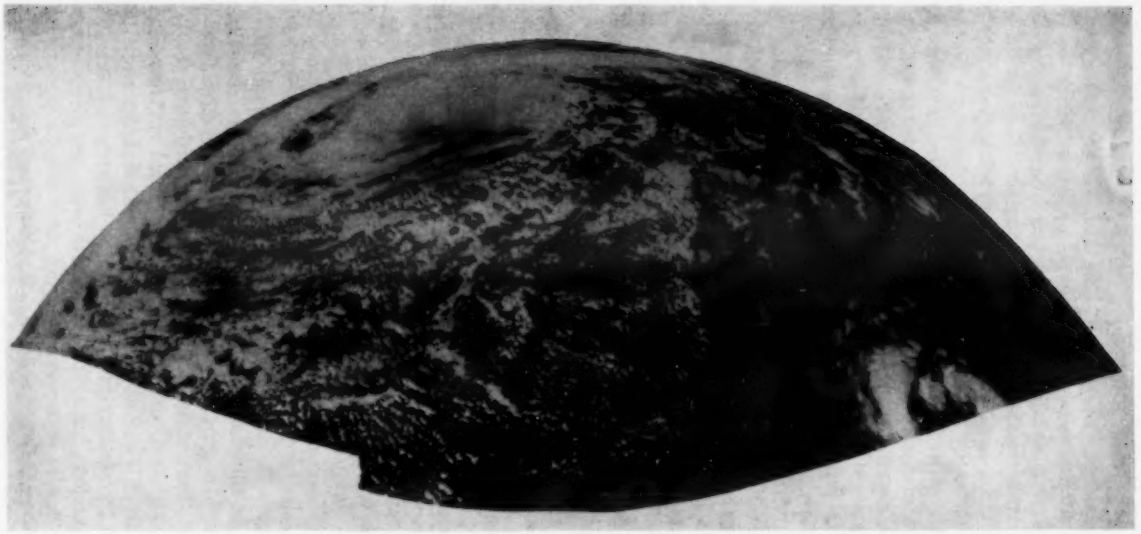


FIG. 2a. Mosaic of original rocket photographs showing "Texas" storm, cloud streets, and other features. In the upper portion, just to the left of center, are clouds spiraling into an old tropical storm. The storm in the lower right portion of the photograph produced a much lighter precipitation.

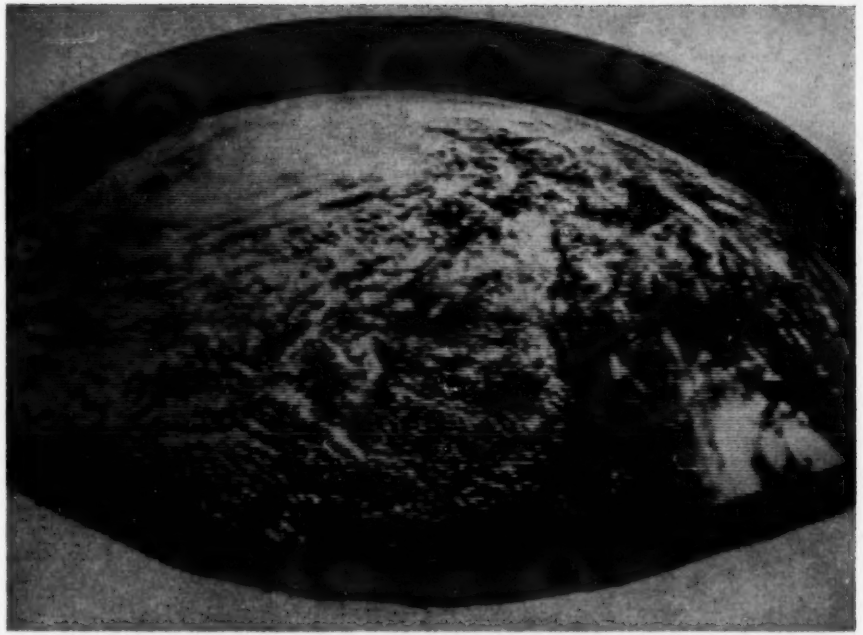


FIG. 2b. The same mosaic photograph as above but as it would probably be viewed from a satellite camera. Television raster lines have been superimposed to give a resolution of about 1 mile/line in the center foreground and about 3 miles/line average resolution over the whole picture.

although the satellite will remain in orbit for many years.

The Vanguard II satellite is a sphere, 20 inches in diameter, weighing 21.5 lbs. The photocells have an angular opening of about 1°, so that for a 300 mile satellite elevation the photocell would see a strip of about 6 miles wide when looking straight down, the width of the strip widening towards the horizon. The satellite spins as it revolves about the Earth in an orbit confined between latitudes 33°N and 33°S. From this spinning satellite the photocells, mounted at 45° to the spin axis, were supposed to sweep out areas on the Earth. The spin rate, elevation, and orbital speed of the satellite were required to have specified values, so that for certain orientations of the spin axis, successive spins of one photocell would sweep out terrestrial areas which would lie side by side to each other. Had these precisely required satellite motions occurred, the signals corresponding to these successive swept-out strips could have been fed into an oscilloscope, which would then have depicted the cloud cover over a wide area.

Unfortunately, the satellite motions were not as planned. The spin rate was different, the elevation was higher, reaching up to 2,064 miles at apogee; and the spin axis itself, which was supposed to be fixed in space, precessed. Thus with these erratic motions, as the photocells swept out areas on the Earth, adjacent strips did not in general lie next to each other. It may still be possible to determine the cloud distribution during individual sweeps; but such information has not yet been made available (June 1959).

2. Television Cameras—Project TIROS

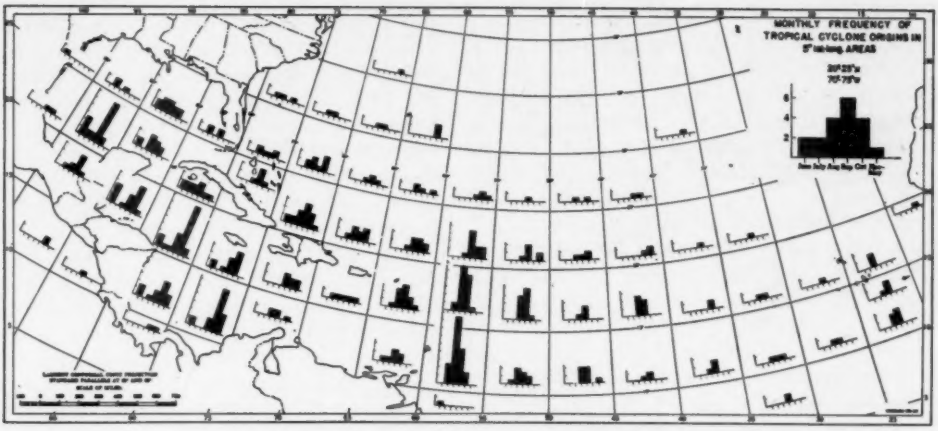
The difficulty introduced by the satellite motions in Vanguard II can in part be overcome in a heavier satellite by using television cameras or by more precise control of the satellite motions. A television camera takes an instantaneous picture of a large area. Thus even if the satellite motions are erratic, provided the spin rate is not too fast, a cloud picture covering a substantial area of the Earth can in general be obtained. Of course, if the satellite motions are not erratic, then it is possible to obtain successive, adjacent or overlapping pictures so that much of the sunlit Earth can be seen systematically during one day.

This is the plan of Project TIROS (10). Project TIROS was originally under the cognizance of the Advanced Research Project Agency (ARPA) of the Defense Department. More recently it has been placed under the management of the National Aeronautics and Space Administration (NASA). This satellite will also be a spinning satellite, weighing considerably more than Vanguard II, and orbiting at several hundred miles above the Earth between about latitude 50°N and 50°S. According to present plan (June 1959) the satellite will contain two television cameras, designed and built by RCA, both "looking" along the spin axis. The cameras will be sensitive to green-red light, to reduce the scattering introduced by the cloudless atmosphere. The television cameras will take "snapshots" when they are viewing the illuminated Earth at favorable angles. The data will be stored on magnetic tape for one orbit and transmitted on command to ground readout stations. On the ground, the data will be received and recorded simultaneously: (1) via a television screen which will be photographed and (2) via a magnetic tape.

One camera will have a field of view, when the spin axis points to the center of the Earth, of about 700 by 700 miles, with a resolution of about 1.5 miles, near the sub-satellite point. The resolution is determined by the number of TV raster lines, the field of view of the camera and the distance from the sub-satellite point; the resolution will therefore be poorer than 1.5 miles as the distance of the viewed area from the sub-satellite point increases. The second TV camera will have a smaller field of view but a higher resolution. Over dark backgrounds, the lower resolution of 1–2 miles will be adequate for observing most cloud features when the cloud elements are more than 1–2 miles apart. Since the entire Project TIROS is an experiment, the various resolutions available will be useful in studying the types of cloud information which can be obtained as a function of resolution.

Even prior to the launching, the effect of resolution is being studied. The Radio Corporation of America has a TV simulator which can reproduce pictures as though they had

(*Continued on page 163*)



The frequency of Tropical Storm origins by months within 5° areas (1899–1958).

Where Hurricanes Begin

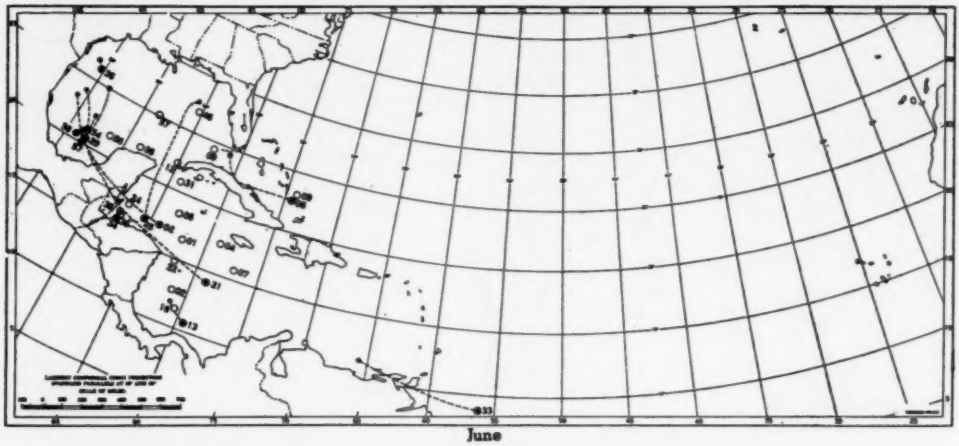
WILLIAM H. HAGGARD, *Office of Climatology, U. S. Weather Bureau*

HURRICANES are tropical storms occurring over the North Atlantic, or extreme eastern North Pacific, with winds of 74 mph (64 knots) or greater. The hurricanes discussed in this paper are restricted to those of the North Atlantic, Caribbean, and Gulf of Mexico. They occur principally in the months from June through October, though occasionally one or more may appear in the remainder of the year. There is a general pattern of area of formation and subsequent motion which undergoes a seasonal cycle. The early and late hurricanes of any season are most likely to begin over the western Atlantic, Caribbean, or over the Gulf of Mexico, while those of "mid-season" (late August and September) most frequently begin over the eastern North Atlantic.

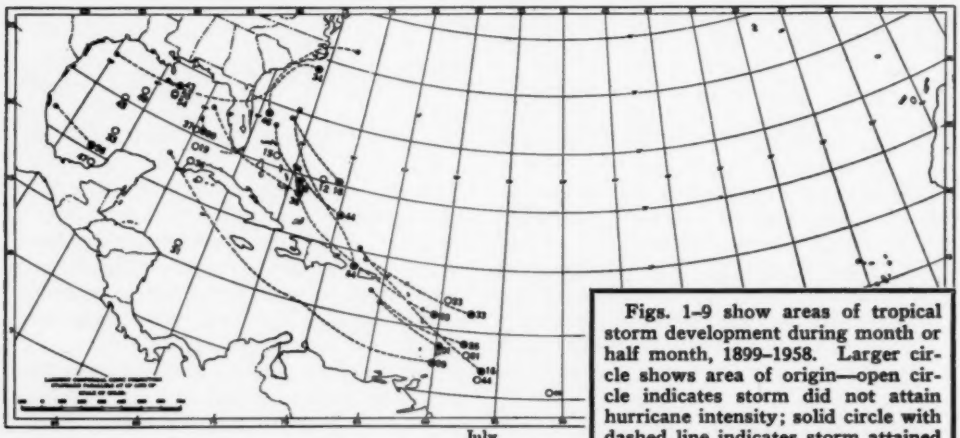
Weather forecasters often use climatological data as a guide to the prediction of storm behavior. The meteorological literature contains several references to differing characteristics of the paths of hurricanes and tropical storms beginning in different areas. A complete climatology of the originating areas of hurricanes and tropical storms has not always been available. The birthplace of any particular tropical storm is difficult to locate with even a reasonable degree of accuracy. Dr. Riehl has pointed out that tropical storms (from which hurricanes develop) form in pre-existing disturbances, waves, or shear lines, and that development may require several days (during which the disturbance moves great distances) or may take place very rapidly in the area of origin (1).

Many important storms have been investigated in detail by various authors, who have selected the point of origin in very different locations along the general path of the disturbance within which the storm developed. Many of these "pre-existing disturbances" can be traced to regions over North Africa. Yet it is difficult to say that hurricanes begin over the Sahara, since we consider them to be storms of tropical oceanic areas. The fully developed tropical storm or hurricane obtains its energy from the condensation of huge quantities of moisture, available in such quantity over tropical oceans. Thus we must consider the beginning of a hurricane to be in that region where the development took place which continued to the full hurricane stage rather than the far more obscure region where the relatively minor initial disturbance, wave, or shear line first formed.

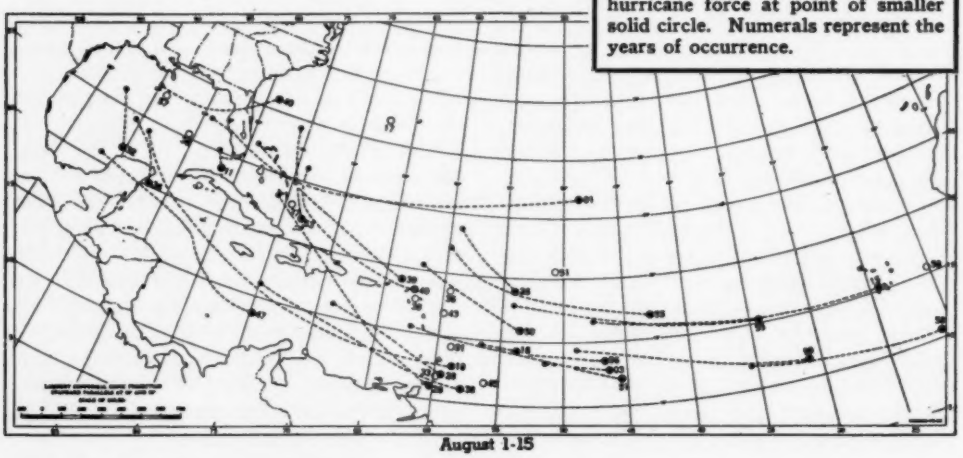
This approach may appear more reasonable when one considers that minor disturbances,



June



July



August 1-15

Figs. 1–9 show areas of tropical storm development during month or half month, 1899–1958. Larger circle shows area of origin—open circle indicates storm did not attain hurricane intensity; solid circle with dashed line indicates storm attained hurricane force at point of smaller solid circle. Numerals represent the years of occurrence.

FIGS. 1–3.

waves, and shear lines are present in quantity on nearly every day's synoptic charts of the tropics, yet only an average of about 10 tropical storms per year develop over the area considered here, of which 5 or 6, on the average, may become hurricanes. In some years no hurricanes will occur, while in others 20 or more tropical storms may develop, with 9 becoming hurricanes. In the years since 1879 at least one tropical storm has developed in each year in the region considered.

Mr. Gordon Dunn, the Weather Bureau's chief hurricane forecaster, in writing of areas of hurricane development stated: "Obviously this area is not a point, yet the concept is meaningless if it is expanded to encompass the entire known existence of the wave prior to the attainment of hurricane intensity" (2). In the February 1956 *Monthly Weather Review,* Dunn located, on the tracks of all tropical storms occurring between 1901 and 1955 reaching hurricane intensity, the point where he believed the storm first reached hurricane intensity.

Dunn's approach was extended by this author to attempt to locate the point on all tropical storm tracks from 1899–1957 where the tropical storm first developed. The results were reported in the October 1958 *Monthly Weather Review,* and are partially repeated in this article.

All tropical storm tracks in the region described earlier, occuring from 1886 through 1958, were examined and adjusted to fit all available data. For the years 1899 through 1958 the tracks were separated into portions according to estimates of the intensity of the storm. The exact point on its track at which a storm attained tropical storm intensity (winds of 34 knots or greater) is naturally somewhat questionable. It is equally difficult to determine precisely where the closed circulation which developed into a tropical storm or hurricane first appeared. In the figures accompanying this article the large circles represent a best estimate of the first location of a closed circulation which later developed into a tropical storm or hurricane. This may be considered as the point where the storm began, even though there may have been a weak pre-existing disturbance on the map for some time prior to this "beginning."

Figures 1 through 9 show the beginning points of North Atlantic tropical storms and hurricanes. The portion of the storm track shown is from its earliest known, or suspected, point of closed circulation (larger solid circle) to the point of hurricane intensity (smaller solid circle.) If the storm did not reach hurricane intensity, the birthplace is shown as an open circle with no track. The numeral beside the circle represents the year in which the storm occurred.

As shown in figure 1, all June developments in the past 60 years were in the Gulf of Mexico or the western Caribbean, with the exception of three storms, one at low latitudes in the Atlantic and two in the Bahamas. No birthplaces were detected east of 55°W. Tropical storms outnumbered hurricanes.

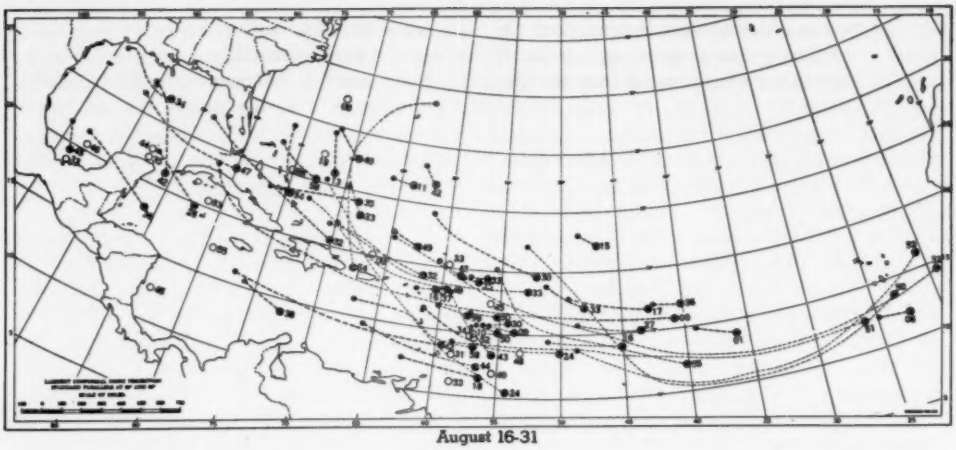
For July (fig. 2), the principal breeding ground shifted away from the western Caribbean. Tropical storms and a few hurricanes originated in the Gulf. The activity was greater than that of June in the Bahamas area and the region east of the Lesser Antilles. In July no birthplaces were detected east of 50°W.; the July origins were, however, well east of the June ones.

For early August (fig. 3), there were fewer origins in the Gulf. Most storms developed in the area just east of the West Indies and several originated (at about latitude 15° over the Atlantic).

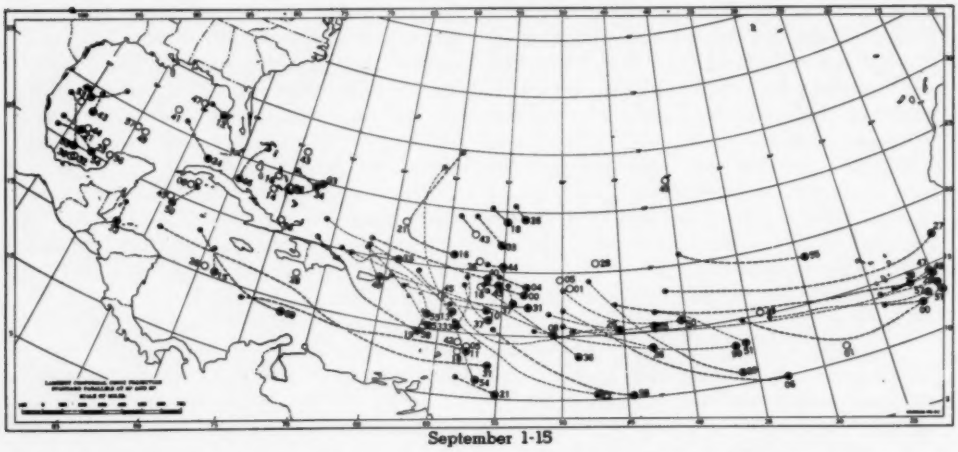
In the latter half of August (fig. 4), the main concentration of development was in the strip from the Bahamas southeastward to 15°N., 50°W., thence between 10°N. and 15°N. eastward to Africa. A large percentage of these storms reached hurricane intensity after only a very short travel over tropical waters.

For the first half of September (fig. 5) more storms originated in low latitudes over the eastern Atlantic, and again the development stages were frequently quite short. A number of storms which attained only tropical storm intensity developed in the southern Gulf, and quite a few circulations started at approximately 55°W., with a considerable northward component to their motion during development.

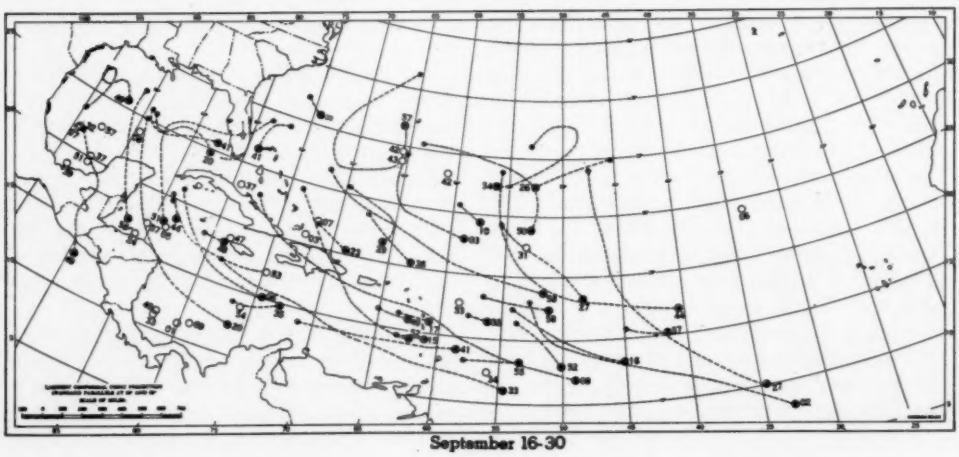
In the last half of September (fig. 6), with the total number of origins decreased, no storms developed so far east as in the early part of the month, and more storms formed at higher latitudes over the western part of the ocean. Developments were again frequent



August 16-31

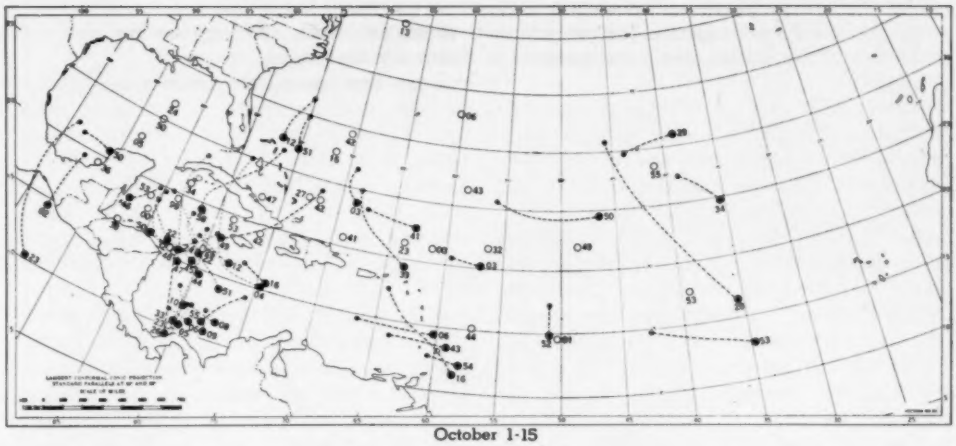


September 1-15

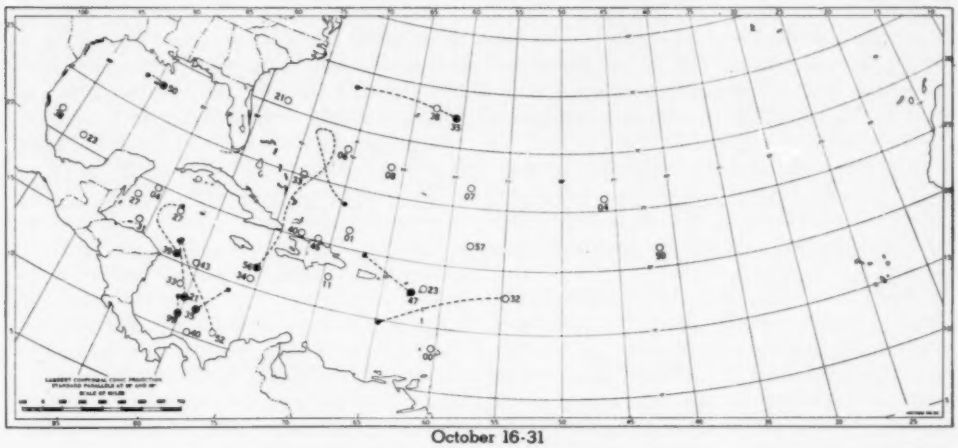


September 16-30

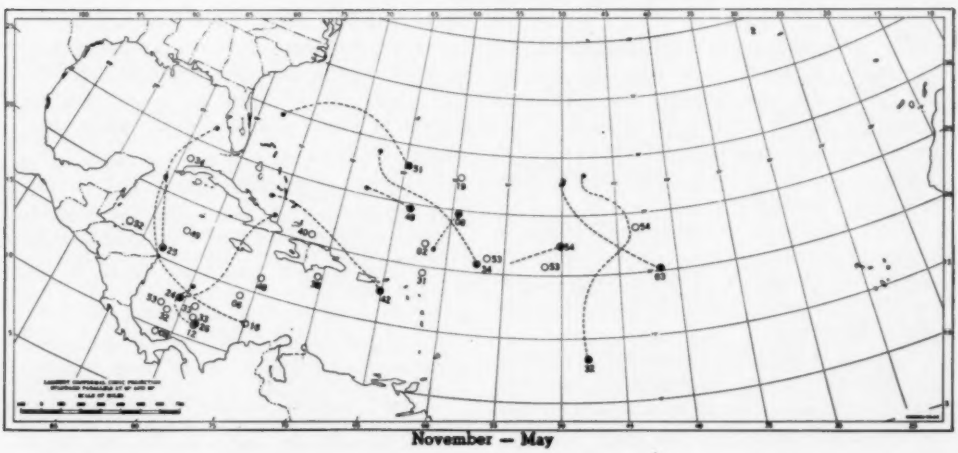
FIGS. 4–6.



October 1-15



October 16-31



November — May

FIGS. 7–9.

in the western Caribbean and southern Gulf areas, but much less frequent in the area just to the east of the Antilles than in the previous 30 days.

In early October (fig. 7), the densest concentration of origins was in the western Caribbean. Developments over the Atlantic were spread over a broad region west of 35°W. and ranging from 11° to 30°N., with one tropical storm in 1913 beginning at 40°N. This storm moved southward and later southwestward to enter the United States coast near Charleston, South Carolina. A few storms developed in the lesser Antilles and two, which had their birthplace in the eastern North Pacific, crossed the Central American Isthmus to enter the Gulf of Mexico.

For the latter half of October (fig. 8), storm activity, greatly reduced in all areas, was mainly in the western Caribbean-Yucatan area. Several tropical storms were spawned over the western Atlantic between 20°N. and 30°N. and three, in 60 years, originated in the Gulf.

For the colder months November through May (fig. 9), origins were scattered over the ocean area northeast of the West Indies and in a concentrated area over the western Caribbean.

The familiar shift from the western Caribbean in June gradually eastward in July and early August to the zone extending across the Atlantic in September and back again to the western Caribbean in the late season is obvious. A few early-season and many September storms have originated over the Gulf of Mexico.

The seasonal maximum of origins east of the lesser Antilles may be real, and not, as had previously been believed, the accidental result of a denser net of observational points. The regular shift eastward and later westward through this region may explain the large maximum found here.

The head chart summarizes the data of figures 1–9 and shows schematically by months the frequency of storm origins over the North Atlantic, the Caribbean, and the Gulf of Mexico.

Many of the tropical storms and hurricanes that have affected the United States had their beginning in areas where a minimum of meteorological observations has been available. The eastern Atlantic, the western Caribbean, and especially the southern Gulf of Mexico are virtual data voids. Yet they are the hurricane breeding grounds.

From this figure one can note the months of frequent or infrequent storm beginnings in each 5 degree area. For example: storms began three times in June, three times in October, once in November and twice in May in the area 10–15°N. and 80–85°W. (early and late season area of origin), while at the same latitude (10–15°N.) and between 20–25°W. storm beginnings have been observed only in August and September, with seven storms beginning there in 60 years during these two months, demonstrating that this is a region where "mid-season" storms begin, as can be seen especially from the September 1–15 chart (fig. 5).

The blank area in the eastern Caribbean representing a region where no origins were detected, tends to support an observation made by C. L. Mitchell in 1924 that this was an area where hurricanes never originate (4). The data of I. R. Tannehill's book *Hurricanes* suggest this same result (5).

The eastern Atlantic, the western Caribbean, and the southern Gulf of Mexico, where hurricanes affecting the coastal areas of the United States begin, are areas where meteorological data are scarce. In recent years the temporary network of the National Hurricane Research Project has provided new data. The reconnaissance of Air Force and Navy Hurricane Hunters provides much needed data when a developing storm is suspected and flights are dispatched. Much credit for early storm detection in these areas must go to the merchant mariners whose regular and special weather reports are often responsible for the first detection of hurricanes and tropical storms in these oceanic regions where hurricanes begin.

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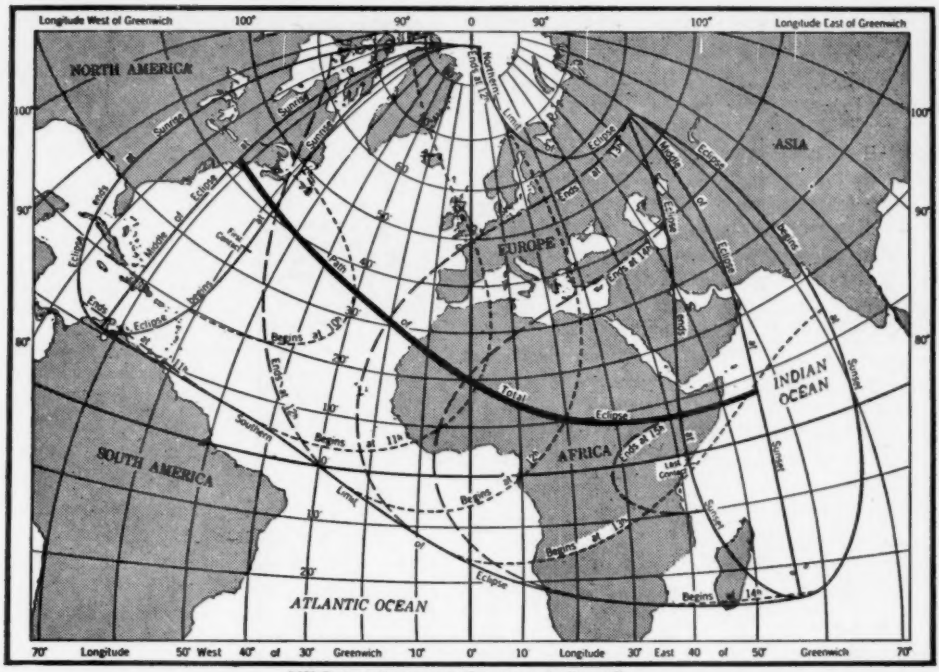


The general circumstances of the 2 October 1959 solar eclipse are indicated in this map reproduced from the 1959 *American Ephemeris and Nautical Almanac*, with the path of totality shown by the heavy line. Courtesy of *Sky and Telescope*.

The Total Solar Eclipse of 2 October 1959

JOHN W. STEWART, *Department of Physics, University of Virginia, Charlottesville, Virginia*

ON Friday, 2 October 1959, there will be a total eclipse of the sun visible at sunrise in eastern Massachusetts and extreme southern New Hampshire. The sun will rise totally eclipsed along a line extending from the southeastern slope of Mt. Monadnock, New Hampshire, southward to a point between South Barre and North Brookfield, Massachusetts. The band of totality in New England is 38 miles in width. Its central line extends from near Templeton, Massachusetts, eastward through Fitchburg, Ayer, Wilmington, Peabody, and out to sea at Salem. The city of Boston lies within the band of totality, near its southern edge. The duration of the total phase on the central line near Templeton will be 55.0 seconds, and at Salem 56.1 seconds. The duration decreases slowly from the central line towards the northern and southern edges of the track. Since the sunrise limit shown on the chart is computed for the instant when the middle of the sun is on the geometrical horizon, with no account taken of atmospheric refraction, the total eclipse will actually be visible at least 50 miles further west.

Sunrise at Boston will occur at 0641 EDST. There the lower edge of the totally eclipsed sun will be only one degree (two solar diameters) above the horizon. The time of mid-totality everywhere on land is within 15 seconds, one way or the other of 0650:20 EDST.

After leaving the Massachusetts coast, the path of totality crosses the Atlantic Ocean

The area of totality in northeastern Massachusetts and southern New Hampshire. Based on data from *Circular No. 78* of the U. S. Naval Observatory. Courtesy of *Sky and Telescope*.

and enters West Africa near Lat. 27°N., Long. 13°W. about noon. It then crosses the Sahara Desert and the upper Nile basin, and ends at sunset in the Indian Ocean off the coast of Italian Somaliland. The maximum duration of totality near the west coast of Africa is 3 min 2 sec.

Astronomers contemplating scientific studies of this eclipse will travel to the Canary Islands or North Africa where they will have the advantages of longer totality, higher sun, and most important, excellent prospects of clear skies. However, the sunrise eclipse to be seen in New England is not without scientific interest, particularly from the standpoint of optical phenomena in the atmosphere. If the weather is clear, it will be an extremely spectacular event.

Weather Prospects

The problem confronting those wishing to observe this total eclipse close to home is whether to locate on the coast (near Salem or Gloucester), or on a hill inland. The primary consideration is that *the eastern horizon must be level.* Even a low hill or tall trees to the east of the observer could hide the sun until after the total phase was over. Anyone planning to observe from an inland site should watch a sunrise from it during the week before the eclipse to make sure that the view is clear. From a coastal point, one would see the sun rise over water and not have to worry about obstructions, except for offshore islands. There one also would have the advantage of maximum altitude of the sun during totality.

After making a study of weather information kindly supplied by the U. S. Weather Bureau stations at Boston's Logan Airport, Concord, New Hampshire, and Worcester, Massachusetts, the writer concludes that chances of clear sky at 0650 EDST on 2 October 1959 are greater on the coast than inland. Hour by hour cloud cover data are available only for Boston, but the prevalence of morning radiation fog is at a maximum inland at this season, while ocean fog is unlikely because, in early autumn, the ocean water is usually warmer than the land.

The period Sept. 25–Oct. 9, inclusive, for each of the last ten years was chosen for analysis. 144 separate daily observations of

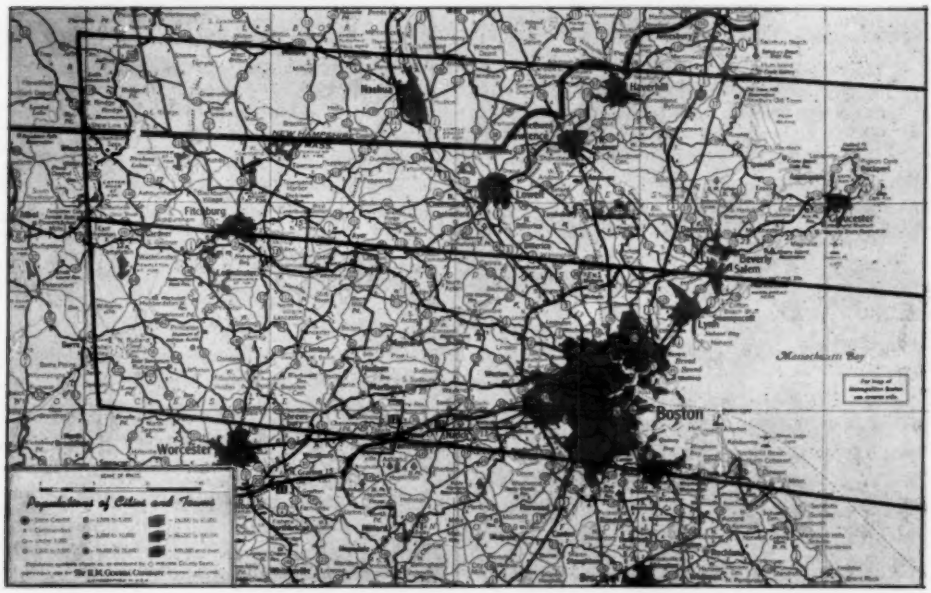
cloud cover at Boston at the times indicated were examined: October 1–9, 1949, 0800 EDST (data not available for Sept. 25–30, 1949); 1950–1955, 0800 EDST; 1956, 0720 EDST; 1957–58, 0700 EDST. These are close enough to the actual time of totality to give a representative picture. The following table shows the results:

Cloud cover (tenths)	Percentage of observations	Cloud cover (tenths)	Percentage of observations
0 (clear)	33	6	4
1	6	7	1
2	3	8	4
3	5	9	5
4	2	10 (overcast)	35
5	2		

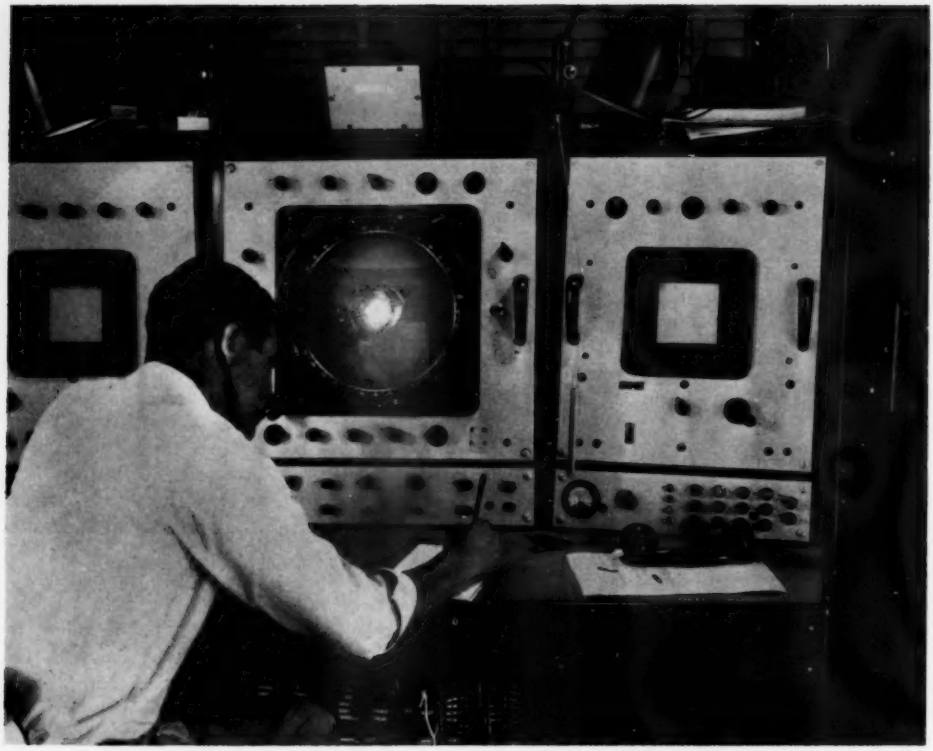
The chances of completely clear sky are about equal to those for a completely overcast sky. The odds that less than half the sky will be obscured are very nearly even. There is no way of telling from the data whether partly cloudy skies at this season and time of day tend to be obscured primarily in the seaward or landward direction. Neither do these data give the type of clouds. On some occasions they might have been cirriform which would not completely prevent observation of the eclipse.

Sunshine data were examined for the same period. For the last ten years the mean percentage of sunshine (sunrise to sunset) at Boston for this two-week period has been 66%—49% of the 150 days had better than 80% of possible sunshine, and 41% had better than 90% sunshine. Early autumn has a relatively high proportion of completely clear days, and is the most favorable season of the year for observing an eclipse in the Boston area. At Concord, New Hampshire (outside the path of totality), the average percentage of sunshine for the same 150 days was 56%. There only 33% of the days had greater than 80% sunshine, and 27% greater than 90%. Much of the difference between Boston and Concord sunshine is the result of formation of cumiliform clouds during the middle of the day at the inland station, and is not significant for this eclipse. The fog data are more important. Thick fog (reducing visibility to

(*Continued on page 165*)



The area of totality of the 2 October 1959 eclipse plotted on a road map of northeastern Massachusetts and southern New Hampshire. Heavy black lines show border of totality area with center line of maximum duration also shown. This copyrighted map reproduced by permission of H. M. Gousha Co. and *Sky and Telescope*.



The control console of the new WSR-57 radar at the Miami Hurricane Research Center. The entire system can be operated from the console which contains all operating controls, monitoring and metering indicators, RHI scope, A/R scope, PPI (direct and off-center) scope, and ranging unit plus all necessary power supplies. Photo courtesy of Gray & Rogers and U. S. Weather Bureau.

Notes on the National Hurricane Research Project

New Weather Radar

THE first of 31 new high-powered WSR-57 radar systems was installed in July in the Hurricane Research Center at Miami, Florida. Other coastal and inland points will receive the new type radars during the next 12 months. A tentative installation schedule will be found on page 178.

The Weather Bureau radar system is designed to locate and plot precipitation areas and associated meteorological phenomena within a radius of 250 miles from a fixed site. The system will operate 23 hours a day over extended periods of time in the face of a wide variety of climatic conditions. Three operating frequencies are available, each with a choice of three pulse widths. The equipment is designed to permit changing frequencies and pulse widths in a minimum of time so that varying types of meteorological events can be studied.

The system has two functions: (1) Searching—The radar set can be used as a search set to locate storm and precipitation areas.

The range of the equipment enables the operator to locate these areas far enough away so that information gained as to their size and rate of travel can be used for advance forecasting of local weather.

(2) Analysis—the radar set can also be used to analyze storm areas. An off-center PPI permits enlarging a selected area for detailed study. A Range Height Indicator (RHI) provides an accurate indication of target altitude and slant range. A Range Indicator plots relative target intensity against distance in the form of a straight line graph. The antenna may be sector-scanned in either azimuth or elevation to permit concentrated study of a particular area. A remote PPI is provided primarily for photographic purposes.

Data Collection

Negotiations are proceeding with countries in the West Indies for continuation of the West Indies Rawinsonde Network. The agreement with Colombia has been concluded calling for a three-year continuation of a station at San Andres Island and for a new station at Bogota. An agreement has been reached with the Netherlands Antilles for continuation of the stations at Curacao and Sint Maarten. Negotiations are continuing with the French regarding the Guadeloupe station, with the Dominican Republic concerning the Sabana de la Mar location, and with the West Indies Federation for the observing points at Kingston, Jamaica, and Grand Cayman. Although negotiations with Mexico are proceeding rather slowly, it is expected that the rawinsonde station at Merida on the Yucatan Peninsula will continue and that there will be some expansion in the services elsewhere in Mexico.

Aircraft Program

Three weather reconnaissance aircraft are being outfitted with new instrumentation and will be ready for the later part of the present hurricane season. A B-57 will be finished first and the DC-6's will follow.

Airborne Weather Recorders

The construction of detachable weather recorders to be flown on the Air Weather Service reconnaissance planes from Bermuda has been completed. These recorders, which are built into modified gasoline tanks and suspended from the wing, can be readily detached and shifted from plane to plane. They are photopanel recorders which will record latitude, longitude, wind direction, wind speed, frame counter, magnetic heading, air speed, pressure altitude, temperature, radar altitude, and time. They utilize the instruments already installed in the aircraft with the exception of the vortex thermometer and timer which are installed directly in the pod. Recording is by the photopanel method and the sampling rate can be varied at the discretion of the meteorologist aboard the plane.

Storm Surge

The Weather Bureau is participating with others in a research program to investigate the mechanism by which wind energy is transferred to the sea in the generation of waves and storm surges. Two offshore research platforms operated by the Navy Mine Detection Laboratory south of Panama City, Florida, will be the scene of part of the program. The platforms are three miles from shore in 30 feet of water, and twelve miles from shore in 100 feet of water.

Rocket Program

The Navy/Weather Bureau hurricane photographic rocket project will have ten complete heads available during the current season. They have been equiped with cameras which have a frame rate of three frames per second with a total film supply lasting 80 seconds. Frame size is $2\frac{1}{4} \times 2\frac{1}{4}$. A beam splitter has been designed so that the photographs are taken along axes at right angles to one another on each frame in order to increase the probability of photographing the area of interest.

Hurricane Beacon

Plans have been completed for a series of hurricane-tracking beacon drops this season.

The beacons which are equipped with a VHF radio transmitter will be dropped by the 59th Weather Reconnaissance Squadron operating out of Bermuda and will be tracked by aircraft of the Squadron. The beacons have been developed under the joint sponsorship of the Geophysics Research Directorate, U.S.A.F., and the Weather Bureau.

Machine Processing

Plans have been completed for the installation of a 650 Computer at the National Hurricane Research Project headquarters in Miami. Data processing will commence this season. The new equipment will greatly speed the reduction of raw data which will be automatically recorded on magnetic tape in the new research aircraft.

Research Unit

An experimental analysis program has been planned for the 1959 hurricane season. New types of analyses will be tested to assist in the solution of the hurricane prediction problem. The program includes the preparation of charts to show selected time section analysis at both low and high levels. Charts showing the distribution of precipitable water and other weather features will be maintained. It is planned to have several teams of research personnel work regular forecast and analysis shifts during the occurrence of an actual hurricane to test forecasts produced by various objective techniques. Statistics will be compiled for verification purposes and to furnish the basis for modification of the objective forecast techniques.

AMS Statement on Hurricanes

(Issued by the American Meteorological Society, June 1959)

HURRICANES affecting the United States are windstorms from the tropics in which the air revolves counterclockwise about a central calm area, the "eye." The strength of the winds must obtain at least 74 mph in order for a tropical weather disturbance to qualify for the title of "hurricane." Maximum wind speeds of 100–150 mph are quite common in hurricanes striking a coast, and as much as 200 mph has occurred according to estimates from structural damage.

The area affected by winds in excess of 74 mph may be as small as 30 miles in diameter, while in large storms this diameter may be as large as 100 miles. Outside of the high-wind core, most hurricanes approaching the United States have a large peripheral area in which the winds are less intense and diminish gradually with increasing distance from the center. The diameter of this peripheral circulation may be as large as 500 miles, but it is only the central area with winds above 74 mph for which hurricane warnings are issued. Most hurricane damage arises from inundations of coastal lands by the sea. Inland, heavy rains may produce river floods, especially in mountainous regions. Rains in the peripheral zone seldom are damaging; more often they prove beneficial as relievers of drought.

Hurricanes are water-born storms. The ones affecting the eastern half of the United States originate in the Gulf of Mexico, the Caribbean Sea, and the tropical Atlantic Ocean. There are always precursors of hurricane formation. They start from weak weather disturbances; usually, though not always, a couple of days are needed for a hurricane to emerge from such a disturbance. When observations are available, these incipient centers can be clearly recognized and followed on weather charts. When intensification is suspected, military reconnaissance aircraft are dispatched to the crucial area to ascertain the state of development. When a hurricane or near-hurricane is found, it is present practice for reconnaissance aircraft to continue patrolling the storm until it strikes land or moves off into the central Atlantic Ocean. When the hurricane is close to the coast, it can be tracked with considerable accuracy with large shore-based radar sets.

From the foregoing statements, it will be seen that a surprise hurricane formation in the

areas covered by detailed weather analysis and within reach of reconnaissance aircraft is very unlikely. At times storms form so close to the coast on the Gulf of Mexico and around Florida that they become a menace to the coast within a short time after their inception. In order to keep the public informed of such possibilities, the United States Weather Bureau issues advisories on storms with strongest winds of as low as 40–50 mph in addition to warnings of hurricanes. The main problem in issuing warnings, however, is that of predicting the course of fully established hurricanes.

It is desirable that the public should be warned at least one day in advance so that adequate protective measures may be taken. In assessing the course of a hurricane, as in all endeavors at prediction, there will be some residual uncertainty which cannot be eliminated by presently known methods. For hurricanes this concerns the place where a storm will strike and the time when it will arrive there. According to present thinking, an excellent result will have been obtained if inaccuracies in hurricane center prediction do not exceed 50 miles. In view of what has been said initially about the extent of hurricane-force winds, this means that the warning area should normally be substantially larger than the area actually sustaining damage.

Because of the time needed for meteorological services to process data and make predictions, the forecaster must look 30–36 hours ahead in order to provide one-day forecasts for the public. On this time scale an accuracy of center prediction within 50 miles is only rarely achieved at present. Hurricanes on the average move at a rate of 12–15 mph in the tropics, but the rate of motion often increases to twice this amount, at times even reaches 50–60 mph, when storms come out of the tropics and impinge on the northeastern United States. Even at a speed of 15 mph, the error in placing a center 36 hours ahead will exceed 50 miles, if the predicted course of the storm is off by as little as 10° on the 360° compass. At higher rates of motion, the error will be correspondingly larger. These brief calculations show that a very high degree of forecast accuracy is needed for predictions useful for the public.

The factors determining storm displacement, and especially changes of path, reside inside the hurricane only to a minor extent. Although considerable proficiency has been achieved in tracking centers and observing their interior with airplane and radar, this information helps very little for warnings except on a very short time scale of a few hours. The longer a forecast is desired, the farther away from the storm area must one look for the controls. For a one-day prediction, observations within 1,000 miles of the hurricane center will normally suffice; weather events in the central and northern United States and in the higher latitudes of the Atlantic Ocean are of particular importance. For a two-or-three-day forecast current weather events in temperate and polar zones over the whole Pacific and Atlantic Oceans, in addition to North America, must be taken into account.

Various researches to develop prediction techniques for hurricanes from large-area studies have been underway for numerous years and are still being pursued. At present, the degree in refinement of calculations has well outrun the accuracy and density of the observations on which the calculations are based In hurricane forecasting, a large number of high-quality oceanic observations are indispensable because calculations must take into account the current state of the atmosphere on all sides of a storm. Currently, these oceanic observations do not exist in nearly sufficient quantity, especially in the upper atmosphere. It is possible to gather such data within reasonable cost limits by means of aircraft, at least for hurricanes that are a potential threat to the continent within two days of their position at any moment. Until such observations are secured, it is unlikely that the error in 36-hour prediction will be reduced to a 50 mile limit.

On a longer time scale of up to 5 days researches are being pursued to develop redic-tion methods useful as a *general guide* on the path of a hurricane. No scientific basis exists for predicting months in advance when and where a hurricane will form or enter the coast.

The subject of possible modification of a hurricane's path or intensity is receiving attention by the profession, but up to the present no conclusive experiments have been performed.

THE SUMMER HEAT HE TAKES IN STRIDE,
HE DON'T MIND FIGHTING FLIES;
BUT WHEN THOSE RAINCLOUDS PASS HIM BY
HE DOGGONE NEARLY CRIES.
HIS LAND'S SO DRY THE HORNY TOADS
HAVE ALL PACKED UP AND GONE;
YET WHEN IT RAINS, IT'S SIX MILES OFF,
RIGHT ON HIS NEIGHBOR'S LAWN.
TOM ELLINWOOD

(Courtesy Arizona Daily Star)

"It Rained Everywhere But Here!"— The Thunderstorm-Encirclement Illusion

JAMES E. MCDONALD, *University of Arizona, Tucson, Arizona*

METEOROLOGISTS working in regions where rain cannot be taken for granted know how often despondent exclamations are made by disappointed farmers and ranchers who dolefully watch summer convective showers occurring on all sides of them as their own dry land goes unwetted by any rain. Experience suggests that the drier the ground underfoot, the greater the tendency to describe an occurrence of airmass showers in terms such as these: "It must have rained on every ranch in the county but ours!" Or, "We were completely surrounded by storms, but somehow or other they all veered around us and the farm didn't get a drop all afternoon."

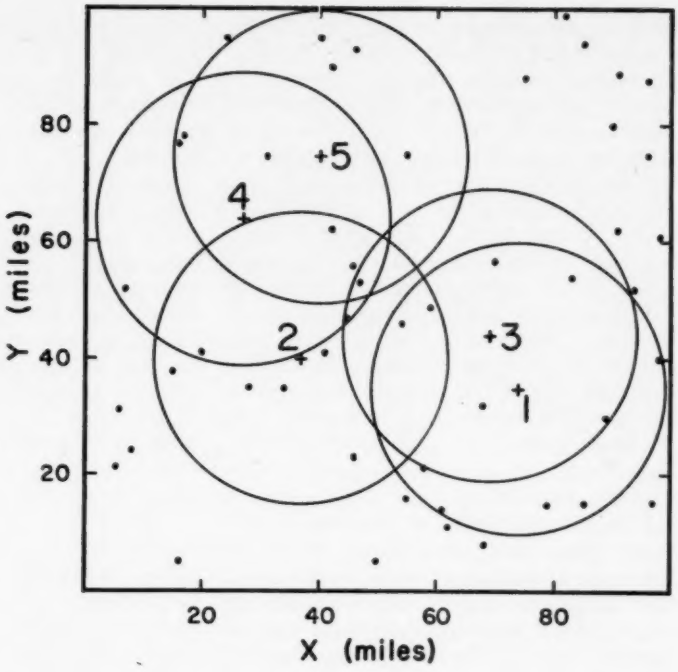


FIG. 1. Hypothetical "storm map" showing locations of 50 thundershowers and five "observers" randomly distributed over an area of 10,000 square miles. Circles of 25-mile radius centered on the observers' locations bound areas of shower detectability for each observer.

Of course there must be occasional cases wherein such gloomy imputations of nature's perversity happen to be essentially correct; but most of the time such comments constitute a grossly mistaken description of what is really taking place. Here I want to point out, through an example, how this "thunderstorm-encirclement illusion" becomes an almost inevitable accompaniment of those summertime synoptic situations that fit so well the weatherman's familiar phrase, "widely scattered thundershowers in the central part of the state."

Since the geometric and statistical nature of the illusion here in question is most convincingly illustrated with an actual graphical model, we may consider a model set up on the following basis: When true airmass thunderstorms break out in fairly level country, the locations of the storms may be regarded as almost randomly located. In an area of 10,000 square miles (a square 100 miles on edge), let there be 50 thunderstorms having rain areas one mile in diameter occurring during the period of observation. We will ignore their motion. We need not be specific as to whether these storms are occurring simultaneously and are observed all at one time, or whether they occur at randomly distributed times over the duration of, say, an afternoon; for our concern here is simply with the overall impression left in the observers' minds. We may assume, as an adequate approximation to reality, that each observer is able to detect a rainshower out to a distance of 25 miles from his location. To assign these 50 storms to chance locations typical of airmass thundershowers, a table of random numbers may be used. In the particular table that I employed, five-digit random numbers were listed, so I used the first 50 numbers, taking the first two digits of each for the x-coordinate (in miles) for a given storm, and the second pairs of digits of each for the associated y-coordinate. The fifth digits were simply ignored. Then, on the resulting "storm-map" (fig. 1), I located five "observers" by further use of the same random numbers table, requiring only that each observer be at least 25 miles from any boundary point of the square in order that all parts of each observer's circle of shower-detecta-

bility lay within the model area. Specifically, I used the first five cases (following the fifty already-used random numbers) wherein the x- and y-coordinates both fell between numerical values of 25 and 75. In the figure, these five observer-locations are indicated by the five numbered crosses. Concentric with each of these five points, a circle of 25-mile radius has been drawn in the figure to bound the area within which each observer is assumed able to detect active thundershowers.

Even casual inspection of the figure shows that each observer will see showers well distributed about the compass. To display this more vividly, the azimuthal locations of all detectable storms have been read from the figure by means of a protractor and were then plotted (fig. 2) without regard to range from the observer.

Note that the number of observed showers ranges from eight (Observer 3) to twelve (Observer 2); and note that in the five cases, there is only a single instance wherein an observer has a storm-free quadrant (Observer 5 sees no storms in his SW quadrant). Imagining how the sky and horizon would look to each of these five randomly located observers, we must admit that each would have apparently good reason to assert that it was raining all around him. But it will be seen (fig. 1) that in this random sampling procedure it turned out that rain did not fall on a single one of the five observers' locations. In fact, the minimum distance from any observer to his nearest storm was 4 miles (Observer 2). Thus the model illustrates the high probability that when airmass showers develop, most farmers and ranchers will be inclined towards hydrometeorological paranoia.

From elementary probability considerations it is possible to supplement the above qualitative conclusions with quantitative statements that show even more convincingly how tempting it must be for a drought-stricken farmer or rancher to think that the rainclouds go out of their way to avoid his land: A circle of 25-mile radius covers 1,960 square miles, or 19.6 per cent of our model area's 10,000 square miles. Hence the expectation value for the number of detected storms per observer is 19.6 per cent of 50 or 9.8, which is surprisingly well approximated by our 5-observer sample mean (10.0). The distribution of number of detectable storms per observer will approximate closely to the binomial distribution, so statistical arguments predict a standard deviation of 2.8 about the mean detectable number of 9.8. Hence, almost 70 per cent of all randomly located observers may be expected to report a number of storms lying in the interval 7.0 to 12.6 storms.

All of these numerical values argue the likelihood that most observers will see a substantial total number of storms, but we must next consider the question of whether these will be fairly well distributed in azimuth.

(*Continued on page 174*)

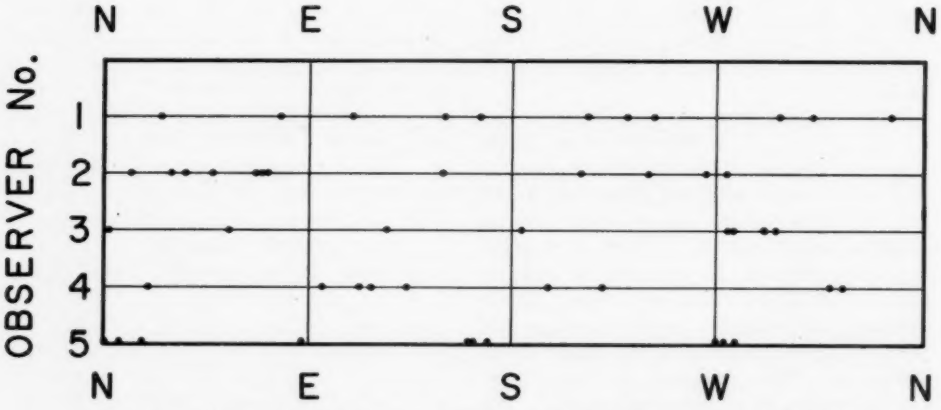


FIG. 2. Azimuthal locations of showers detected by each of the five observers in figure 1.

The Northumberland Strait Storm in Canada

K. T. McLeod, *Canadian Meteorological Service*

AN intense storm covering a relatively small area moved inland on 19 June 1959 from the Atlantic Ocean in a northwesterly direction over the Maritime Provinces adjoining Cabot Strait and Northumberland Strait in the southern Gulf of St. Lawrence area. The accompanying gales created a very hazardous wave situation which caught some fifty salmon boats out on the fishing area where the high waves swamped some of the boats with a considerable loss of life resulting.

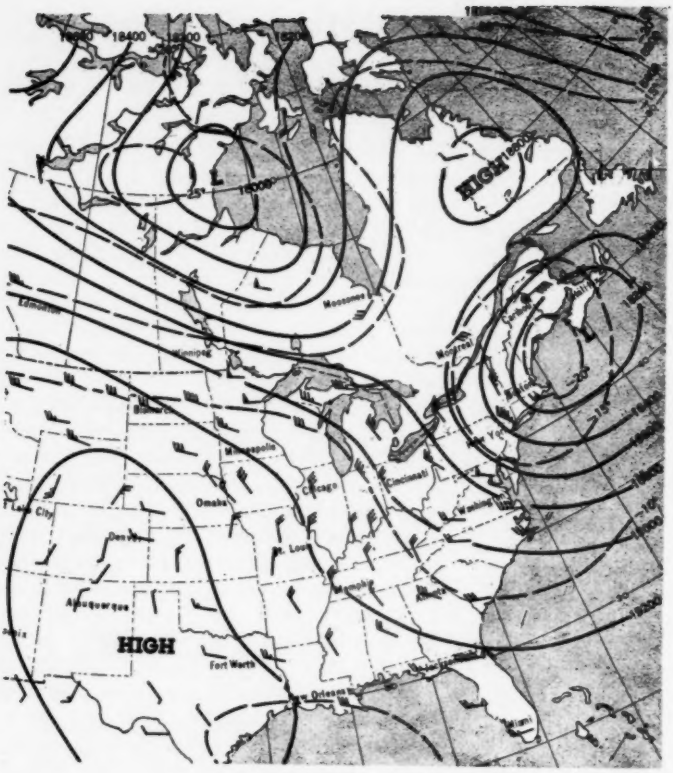
From June 14th to 18th the East Coast weather had been of a stable repetitive type.

Path of Northumberland Strait Storm on 17–21 June 1959 as plotted by U. S. Weather Bureau. Circles indicate position at 0700 EST on date shown.

An area of high barometric pressure over Newfoundland with an extension to the north had blocked the usual easterly movement of weather systems over Canada and the northern States. A series of storm centres with associated cloud and rain moved northeastward over the Atlantic Ocean off the United States coast. Each intensified slowly—then, blocked by the high pressure system ahead, recurved to the northwest and west and died away over New England. On the 1400 EST weather chart of June 18th another in the series of storm centres was drawn in at a position about 200 miles south of Cape Hatteras. Two hundred miles further south a ship report indicated a strong local wind (about 40 mph). From past experience this could be due to an error in coding or in transmission, or in the position of the ship. The scattered ship reports received at six hour intervals tracked the storm centre off Hatteras towards the northeast, but for eighteen hours no reports were received to confirm or rule out the possibility of the second storm area 200 miles to the south.

The network of reports received in the usual coded form during the morning and afternoon of Friday were difficult to analyze. A double system appeared probable with separate, but partially-merged cloud, rain, and wind fields. The plotted reports were insufficient to fix the locations of centres of areas of gale winds, and the future paths of the whole complex and of parts of the system were difficult to predict.

At 1800 the Sable Island weather station reported a wind of 26 mph from the east. The wind had been increasing gradually hour by hour during the day. In the next two hours the wind increased sharply to 46 mph from the east-southeast and light rain began, indicating the approach of a severe small area storm. Subsequent reports from a network of land stations gave definite positions to the centre of the storm, with its localized area of counter-clockwise gale winds, as it swung inland curving to a near stop over northwestern Nova Scotia.



The 500-Millibar Constant Pressure Chart for 1900, 19 June 1959, showing vortex over Gulf of Maine and blocking high over Labrador. Chart represents conditions at approximately 20,000 ft. USWB chart.

The movement and changing intensity of weather areas (wind, precipitation and turbulent clouds associated with an area of low pressure) are governed largely by the characteristics of the air aloft which flows in giant rivers, whirls and wavelike motions. The contrasting temperatures, wind, and moisture of adjacent air masses moving in often opposite directions at different speeds create instabilities. Eddies are generated that grow in size and intensity and by their ascending air flows lead to the cloud, rain and wind of the storms that daily move over the weather maps.

From June 14th to 18th a giant whirlpool of air was centred aloft over Boston. Small weather systems at lower levels were carried in the flow around this centre. They moved northeastward off the United States coast and later recurved westward in over the mainland. The United States Weather Bureau Numerical Weather Prediction Unit, which has been predicting upper level wind and pressure patterns with a high order of accuracy, forecast no change in position of this centre for the morning of the 20th. The regular wavelike motion of the recent weather centres to the northeast was expected to hold for the future movement of the wave off Hatteras on the evening of the 18th. But aloft the picture changed. The vortex over Boston commenced moving to the northeast and colder air began to feed into the west-east flow to the north. The wave off Hatteras recurved to move in under the Boston upper-air low pressure area. The small storm to the south, which proved to be of a tropical nature resembling a miniature hurricane with central calm area or eye, moved with increasing speed and gradually merged with the other storm to produce, over the Maritimes, greatly intensified conditions resembling in some ways those of Hurricane Hazel in 1954 over southern Ontario.

A tropical storm of this nature is an ex-

(*Continued on page 176*)

Satellite Observations

(*Continued from page 144*)

been taken with television cameras. A rocket cloud photograph can be placed into the simulator, which then televises the picture and produces another photograph on which a predetermined number of raster lines has been introduced.

Fig. 2 (b) shows the "Texas storm" rocket picture with television raster lines superimposed. This gives a "resolution" of about one mile per raster line in the center foreground of the picture. On comparing figure 2 (a) with 2 (b), we see that very little information has been lost in the foreground. This, doubtless, is due to the fact that the spaces between the cloud features are mainly larger than one mile. The cloud "streets" in the lower left-center of the picture are about 3 miles apart and are well preserved. However, the individual elements along one cloud "street" are sometimes less than a mile apart. Therefore, the individual lines in the cloud street have fewer irregularities in the televised picture, figure 2 (b), than in the original photograph, figure 2 (a).

The resolution becomes poorer as one approaches the horizon, and probably averages more than ten miles per line in the upper half of the picture. Nevertheless even in this case, the major features are retained. But now, of course, we are dealing with a cloud field in which large cloud elements predominate and in which spaces between clouds are also large. Therefore, the overcast area in the vortex is correctly shown, and the suggestion of a vortex is preserved.

The large semicircular cloud in the lower right hand portion of figure 2 is also preserved since the spaces are much larger than the "resolution" distance of the television picture in that area.

From this discussion, we should expect to be able to detect and recognize considerable cloud detail from Project TIROS especially when the cameras are pointing straight down. For in that case, the resolution will be about 1.5 miles/line for the camera with the poorer resolution, and on many occasions the cloud elements will doubtless be further apart than 1.5 miles.

Study of rocket and airplane pictures with the RCA simulator has already indicated that the background contrast, orientation of cloud "streets" with respect to the raster lines, and other effects are factors which influence the amount of cloud information which can be obtained with a given number of raster lines per picture frame.

Various agencies are formulating plans to scrutinize the cloud pictures received at the readout stations as soon after receipt as the pictures can be processed. This will provide an "operational experiment" to see whether even with the first fairly complicated, spinning satellite, operational information can be obtained.

The cloud data will also be sent later to a central place for more careful processing; it will then be available for research programs such as the determination of atmospheric structure from the various features in the photographs. The type of information which can be obtained from high level pictures has been discussed by several authors (7, 11, 12, 13).

3. Filters—Nighttime Cloud Cover—Project TIROS

The television cameras will yield cloud information only for the sunlit Earth. Project TIROS may also eventually carry instruments with various filters. The angular opening of these instruments will be about five degrees, so that the resolution will be poorer than the TV cloud picture. Nevertheless it may be possible to detect large cloud systems with one or more of the radiation detectors, although those devices were not designed primarily for cloud detection. The spectral intervals to which the instruments will be sensitive are:

a. 0.2 to 6.0 microns (mainly reflected solar radiation)

b. 7.2 to 35 microns (emitted terrestrial radiation)

c. 8.5 to 11.5 microns (water vapor window)

d. 5.9 to 6.7 microns (water vapor band)

e. 0.6 to 0.8 micron (daytime cloud cover detector)

Each of the first three sensors may indicate the location of the large scale cloud masses at night.

Future Possibilities

1. General

a. *Orbit and observation frequency*

The Vanguard and TIROS satellites will not be in polar orbits; thus they cannot reveal the world-wide cloud distribution. Therefore, future satellites will doubtless include cloud detecting devices flown in polar orbits.

Moreover, a single polar-orbit satellite, whose period of revolution is a few hours can "view" every point on earth only twice in 24 hours. Yet clouds have diurnal and synoptic variations which are significant in less than 24 hours. Therefore, to observe these changes, several satellites may eventually revolve about the earth simultaneously in different polar orbits. It should be noted that a satellite placed into orbit so that it passes somewhat to the west of the pole, will cross the equator at the same local time during each revolution for a long time. Thus it would be possible to have 10 AM, noon, 2 PM, etc, satellites; these times would be approximately the same in middle latitudes as they would be at the equator.

For some developments it would be of interest to have continuous cloud observations. For example in looking for the initial phases of tropical storm development, and in tracking such storms, continuous observation would be useful. These continuous observations can be made from a satellite located at about 22,000 miles from the Earth because such a satellite remains stationary above a point at the equator. Consequently a television device can be trained on the area in question and cloud pictures can be transmitted to a ground receiver as frequently as desired. In the case of tropical storms, the characteristic vortex would reveal the location and motion of the storm.

b. *Attitude stabilization*

Vanguard and TIROS are spinning satellites. In the case of TIROS, the spin axis is expected to remain fixed with respect to the stars, so that the TV cameras will not usually "look" straight down at the Earth. Generally the picture will be taken at some angle to the local vertical at the Earth, so that geographic features and hence cloud features will be considerably distorted. To remove much of these distortions and to facilitate the picture interpretation, attitude-stabilized satellites will be launched. On these satellites, television cameras can be pointed straight down, to obtain an undistorted cloud picture of much of the area viewed.

2. Method of Observation

a. *Photocells, television and infra-red detectors*

With the attitude-stabilized satellite in polar orbits, television camera pictures can be obtained with resolutions of a mile or less for the whole Earth. Moreover, if the stabilization is good enough, photocells can again be used to scan perpendicularly to the satellite's orbit.

These devices can at present be used in daylight. But as more sensitive devices become available, it will be possible to observe the clouds by reflected moonlight and perhaps by reflected starlight, so that clouds will be observed both day and night.

Sensitive infra-red detectors may also become available to view clouds at night with high resolution.

b. *Recoverable film*

Whenever cloud observations are transmitted by radio communication, some loss of resolution occurs. Yet it would be desirable to ascertain the extent to which information is lost by this method. Therefore, during selected situations it may be possible to take photographs on films simultaneously with electronic cloud picture transmission. The film could be placed in a recoverable capsule and sent back to Earth for developing. This film, with its very high resolution, could then be compared with the previously transmitted pictures to determine the loss of information by the electronic method.

c. *Radar*

When radar is placed on satellites, it will yield precipitation observations over portions of the Earth. But radar of short enough wavelength can also detect clouds; and if cloud layers are sufficiently separated in the vertical, radar can indicate the height of the respective layers.

d. *Man*

Both for research and for operations, meteorologists will need observing devices which can give good observations for long period of time. Power supplies, either nuclear or solar, will eventually be adequate for long-lived devices. But reliability will doubtless require

that electronic and other components be adjusted, checked and replaced from time to time. When the "man-in-space" becomes a commonplace reality for other programs, one of his functions may be to service observational equipment. At that time we can reliably expect to obtain synoptic cloud data regularly for a long time from a relatively small number of satellites.

Conclusion

It is clear from the work already done in Vanguard II and on Project TIROS, that meteorological data from satellites will soon be available in copious amounts; among these will be cloud pictures with various resolutions from large sections of the world. To make the best use of this cloud information, research is needed to interpret cloud pictures in terms of horizontal and vertical motions of the atmosphere, (vortices, cloud streets, and cloud layers), in terms of static stability (e.g., cumuloform, stratiform clouds) and in terms of anticyclonic vs. cyclonic regions (cloudless areas vs. cloud areas with distinctive patterns). But it is also clear that the knowledge already available about these matters will permit us to deduce new features about the global atmosphere from satellite observations.

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Solar Eclipse (*Continued from page 153*)

¼ mile or less) occurred at Boston on only 8% of the days under study, at Concord on 31% of the days, and at Worcester on 22% of a smaller number of days (only Oct. 1–9, 1957 and 1958 examined for Worcester). Since fog is likely to occur in the early morning hours, this is the most important factor to be considered in the choice of an observing site. Concord, on the Merrimack River, is an extreme case, but inland radiation fog often covers considerably more territory than the river bottoms.

The writer hopes to travel to Massachusetts to see this eclipse. On the basis of the above his inclination is to choose a coastal location near the center of the path of totality, with a clear sea horizon to the east. Because of overnight smoke accumulation the city of Boston would not be a desirable location, although one might obtain a sufficiently clear view from the top of a tall building. The chances of the eclipse being visible appear to be at least even—considerably better odds than many astronomers have faced when traveling to observe an eclipse in far-away tropical locations. It might be pointed out that eight of the last ten October 2's have had greater than 80% sunshine in Boston, but, lest this make the reader too optimistic, we must also note that not a single one of the past ten September 30's has had as much as 80% sunshine!

The Moon's Shadow

The main scientific interest of this eclipse will not be so much in the view of the eclipsed sun and the corona, spectacular as that will be, as in the accompanying general sky illumination. This will be of interest even if

the sky is not completely clear. Under the best atmospheric conditions, it is almost impossible to see detail in the corona with the sun so close to the horizon. At the sunrise eclipse of 9 July 1945 in Idaho, only the inner corona was seen. With the low sun, the moon's shadow can produce interesting and little known effects that do not occur otherwise. There is an opportunity here for amateur meteorologists and astronomers to make a real contribution.

At an eclipse seen near local noon the moon's shadow travels more or less parallel to the ground at 1,000 miles per hour or more. It appears in the west and departs in the east. At mid-totality, the illumination is nearly the same all around the horizon. On the other hand, in an eclipse such as this one seen near sunrise, the shadow approaches the observer from nearly directly overhead at 2,000 miles per hour. Its effective speed of travel from west to east along the ground is considerably greater. At a sunset eclipse, on the other hand, the shadow would appear to rise out of the ground.

As totality approaches on 2 October, one should look for the shadow directly overhead. It will become visible perhaps 20 seconds before second contact as a dark band extending almost entirely across the sky from west to east. This band will expand in apparent width as the shadow "falls down" on the observer, and will engulf him as the eclipse becomes total. At the end of totality the shadow appears to "drop into the ground," and the only dark area then visible in the sky will be a narrow cone between the sun and the eastern horizon. A thin cirriform overcast should not interfere greatly with observations of the shadow even if the sun itself is obscured.

At a given instant the intersection of the shadow with the ground near the sunrise point will be a long narrow ellipse. Its short diameter, extending north and south, will be about 38 miles, while its long east-west axis will span nearly two hundred miles. Therefore at mid-totality it will become quite dark nearly all the way down to the eastern and western horizons. What illumination there is in these directions should be reddish in color. However, to the north and south the sun will be shining within at most 19 miles of the observer, and a considerable amount of daylight of nearly normal color will be scattered into the shadow by the illuminated air. If the sky is clear, it probably will be light enough during totality to read a watch or newsprint. Brighter stars will become visible. Venus is the only bright planet which will be above the horizon during the eclipse. It will be very conspicuous some distance above and to the right of the eclipsed sun.

Those living in eastern New England outside the path of totality who are unable to travel on the morning of 2 October will still find this eclipse interesting. For a full discussion of the illumination effects to be expected both within and outside the path of totality of a sunrise eclipse, see John Q. Stewart, "The Shadow of the Moon," *Sky and Telescope*, May, 1945, and John Q. Stewart and W. L. Hopkins, *Popular Astronomy*, Vol. LIII, No. 10, December 1945, and Vol. LIV, No. 1, January 1946. These articles contain valuable suggestions for amateurs wishing to observe the eclipse and the moon's shadow. From the standpoint of accessibility, the 1959 eclipse affords a better opportunity than did the 1945 Idaho-Montana eclipse for the observations of the moon's shadow near sunrise. Unfortunately, the weather prospects are not so good in 1959 as they were in 1945.

People living within about 100 miles north or south of the eclipse track should look for the moon's shadow in the air a minute or two before 0650 EDST. With clear sky it should be visible at least that far. If you live north of the track, look towards the southern horizon; if south, towards the northern horizon. If the morning is clear, Mt. Washington in the White Mountains of northern New Hampshire should afford a good view of the shadow some 100 miles to the south. Of course outside the track, the eclipse itself will only be partial. For fear of damaging the eyes, one should observe the partial phases of any eclipse only through smoked glass or darkened film.

Those who live on or near the westward projection of the eclipse track beyond the sunrise point in Massachusetts will have the opportunity to see the still more interesting phenomenon of the darkening by the moon's shadow of the upper atmosphere over their heads *before sunrise*. The area from which this can be seen will include southern Vermont, western Massachusetts, extreme northwestern

Connecticut, and a band at least 200 miles wide across New York State, centered roughly on the Albany-Syracuse-Buffalo line. If you live within this band start looking overhead, or a little to the north or south, at 0645 EDST or 0545 EST. The shadow will appear at nearly 0650 EDST as a black band extending east and west, and should darken the twilight then prevailing. The shadow will "fall" more or less towards the observer until, a few seconds later, it intersects the edge of the earth's shadow in the air overhead and disappears. *This phenomenon will last only a few seconds, so to see it at all one needs to keep alert.* No doubt it will inspire a new crop of flying saucer reports. A bit later the sun will rise still more or less partially eclipsed—the further west the less the eclipse.

It is not known how far west the shadow will be visible in the twilight sky. This phenomenon has never been adequately observed, as relatively few total eclipses have their sunrise or sunset points over populated territory. On 9 July 1945 the moon's shadow was seen well before sunrise from Portland, Oregon, 330 miles west-northwest of the sunrise point near Cascade, Idaho. Portland is 250 miles northwest of the nearest point on the westward projection of the 1945 track! On 30 June 1954 the shadow in the sky was observed and photographed from points in Colorado, more than 300 miles west of the sunrise point.

In the past travelling astronomers have naturally been more interested in other purely astronomical aspects of eclipses, and have been reluctant to place themselves where they could not see the total eclipse. Residents of southern Ontario in the neighborhood of the line Buffalo-London-Sarnia should, if the sky is clear, look for the moon's shadow in the twilit eastern sky just before 0550 EST. Times of sunrise are 0613 EST at Buffalo and 0627 EST at Sarnia. In the deeper twilight across Michigan (Port Huron-Muskegon) the chances of seeing the shadow become slim, but nevertheless it should be looked for fairly low in the east beginning at 0545 EST. One can there expect at most a fleeting glimse, and the sky may be too dark for even that. Sunrise on October 2 occurs at 0643 EST at Muskegon. The sun will rise there just as the partial eclipse is ending.

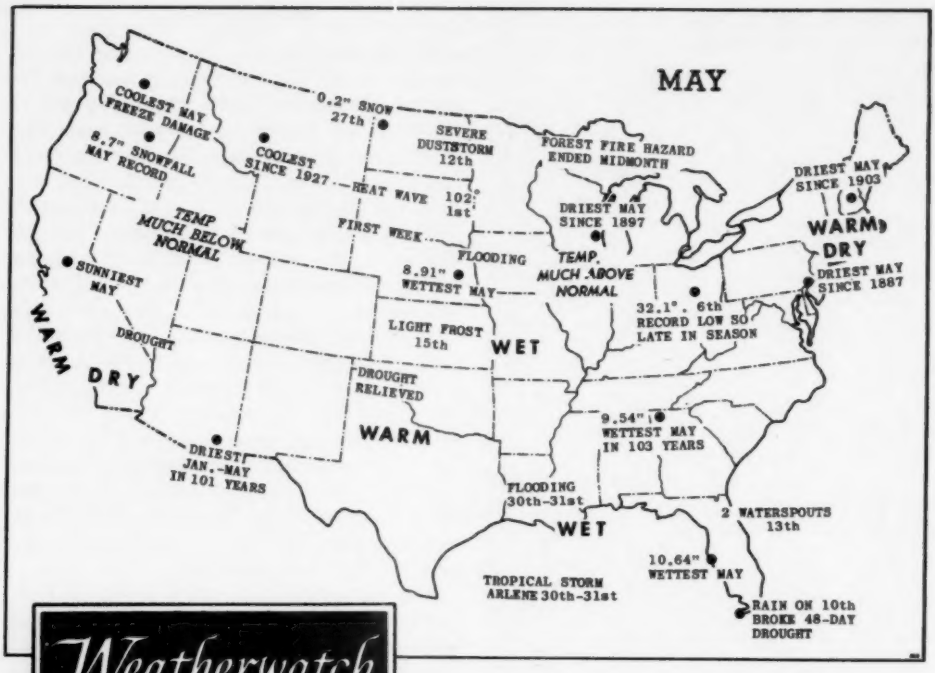
Other Eclipses

On the average, a particular spot on the earth's surface falls within the path of the moon's shadow only once every 360 years. Recently the northeastern states have had better than average luck for observing total eclipses of the sun. The eclipse of 24 January 1925 was total in New York and Connecticut. That of 31 August 1932 (witnessed by the author at the age of five) was visible in northern Vermont and New Hampshire, western Maine, and the tip of Cape Cod. This year eastern Massachusetts lies within the path of totality. On 20 July 1963 a total solar eclipse will be visible in central Maine. The width of the path of totality of that eclipse is about 50 miles. Its central line passes near Trois Rivieres and Megantic, Quebec, and Cambridge, Newport, Bucksport, and Bar Harbor, Maine. Totality will occur in Maine at about 1745 EDST (2½ hours before sunset) and will last one minute.

The remainder of the 20th century affords few additional opportunities for observation of total solar eclipses in the continental United States. Only one is really promising, the eclipse visible in central Florida on 7 March 1970 at about noon. Totality will last over three minutes. On the morning of 26 February 1979 an eclipse will be visible in the Pacific Northwest during the height of the winter rainy season. The eclipse of 30 May 1984 will be annular-total, and may be total for a second or two in coastal North Carolina or Virginia.

Weather FM

Senator Theodore Francis Green of Rhode Island has recently recommended the establishment of a number of FM broadcasting stations to be operated by the U. S. Weather Bureau "for the sole purpose of transmitting warnings, forecasts, and other weather information continuously throughout the day and night." Senator Green has asked the FCC to investigate the feasibility of assigning a suitable number of FM wavelengths for exclusive Weather Bureau use before proceeding with the formulation of appropriate legislation.



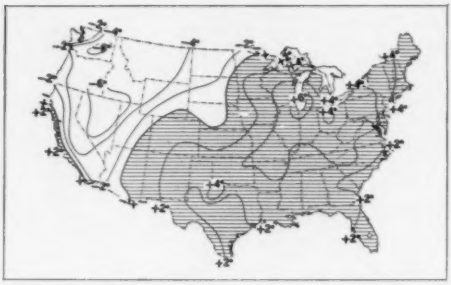
Data by Office of Climatology, USWB.

May and June Reverse Roles

DAVID M. LUDLUM, *Editor*

The merry month of May 1959 produced much more of meteorological interest than did either of the two preceding months reviewed in our last issue. March and April had been quite devoid of severe local storm situations as trouble-making tropical air from the Gulf of Mexico, normally loaded with moisture and heat energy, had been unable to make any sustained headway northwestward into the usual spring storm belt. But the situation changed about May Day when fronts commenced moving slowly eastward across the Great Plains, air masses clashed from the Rockies to the Appalachians, and frequent cyclogenesis took place in the Missouri and Mississippi Valleys, resulting in a turbulent time. Excessive precipitation, damaging hail and thunderstorms, and here and there tornadoes and funnel clouds made headlines.

MAY CIRCULATION—The upper-air circulation over the United States in May divides readily into three phases. As the month opened an energetic trough overlay the Pacific States with a low center in Nevada extending fronts northeastward to the Dakotas and southwestward into the Pacific Ocean off southern California, encircling on the north and west a great bulge of warm tropical air which had been drawn into the great central valleys by the southwesterly circulation preceding the Pacific Coast trough. The movement of hot air from the desert Southwest carried as far northward as the Dakotas where on the 1st and 2nd of May many record date temperatures and maximum-so-early-in-the-season marks were established. The peak of 102° in northeastern South Dakota on 1 May was unprecedented; and the marks established on the first two days of May were in many cases the warmest readings for the entire month of May. Further east, Chicago's Midway Airport reported four consecutive days with 87° or higher. A strong ridge over the central part of the country formed the backbone of the vast sweep of southerly winds. As the ridge moved eastward on 3–5 May, the southerly flow aloft soon tapped air streams directly from the warm, moist Gulf of Mexico, so for the first time in many months moisture-laden Gulf air carried precipitation over the parching Great Plains to the Canadian border and beyond. As if to forecast the pattern of the month, the central ridge drifted eastward rather slowly in the north while the southern segment remained almost stationary, an orientation



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

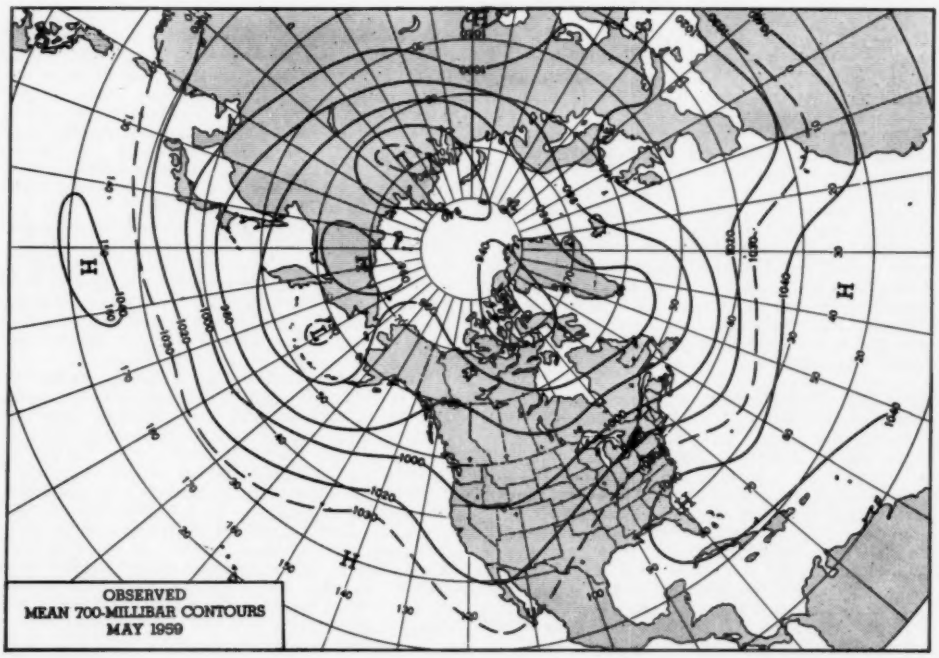
Total Precipitation in inches. USWB chart.

which turned the upper winds from south back to southwest over the central part of the country. Meanwhile another trough formed over the Plateau to repeat on 6–9 May the weather events which had opened the month—first a singeing heat wave and then tropical downpours visited areas immediately east of the Rockies.

The second phase of May weather commenced on the 9th as a frontal system swept in from the Pacific Ocean, moved rapidly across the Plateau and Rocky Mountains, and by noon of the 11th rested on the Fargo-Omaha line. The low center, whose track had remained just north of the United States border, developed an unusual frontal system much resembling a letter T—to the north above the crossbar lay cold, continental, polar air; to the west of the upright there was cool, dry Pacific air; and to the east lay warm, moist tropical air. When the center reached the vicinity of Lake Winnepeg in Manitoba, its pace slowed markedly, first looping southeastward and then gradually drifting northnortheastward to a point just south of Hudson Bay. The contrasting air masses in close proximity

(*Continued on page 172*)

The upper-air map below shows the pattern of air flow for May at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.



Weatherwatch

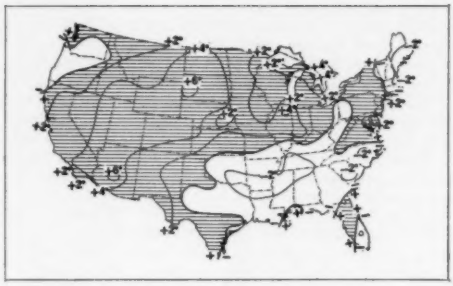
A striking reversal in circulation pattern and weather types took place at the close of May and the opening of June. In the previous month practically all areas west of the Great Divide and eastward over the northern Plains had been decidedly cold for the season; but the southern Plains and all eastward of the Mississippi River had enjoyed a pleasant, warm May. Now in June East and West changed roles. All of the West, again excepting the southern Plains, experienced a very warm June, the warmest ever in some areas. It was rather cool, however, from central Oklahoma and Texas eastward across the Southern States to the Atlantic Ocean; and the Northeast, where May had given an authentic preview of summer with both heat and drought, now complained of record-breaking cloudiness and below normal temperatures, a combination which discouraged early vacationers.

CIRCULATION—High pressure ridges of vast dimensions controlled the weather pattern over continental United States during June. The shifting positions of the upper-air ridges, extending northward as great bulges from the semi-permanent tropical high pressure area, were able to block the normal west-east flow of air currents across the country. From the 13th to the 20th the index of westerly flow aloft reached a remarkably low point as a massive blocking ridge formed in southeastern Canada, and it was during this period that most of the spectacular weather events took place. The main ridge during this period lay just east of the Rocky Mountains, bringing in a southwesterly flow which carried very warm air over the Pacific Coast and Plateau States. In the central area over the Great Plains the same flow of warm air, subsiding in the center of the broad ridge, kept skies clear and permitted a maximum of solar radiation to produce a hot and dry period there. The departures from normal during this two-week period were of sufficient magnitude to cause a *much above* temperature departure for the entire month over a vast area from southern California to the Dakotas.

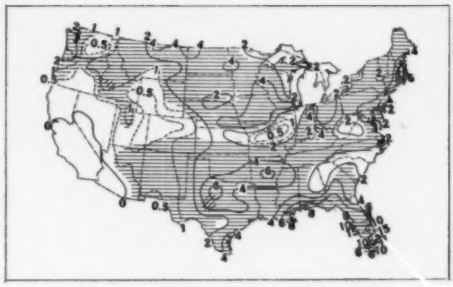
As June opened, a ridge occupied the Plateau and Pacific States with 100°-plus temperatures over the desert Southwest, while a well-marked trough along the Atlantic Coast produced a much-needed rain in the droughty Middle Atlantic and New England States. Amounts from Maryland northward ran between two and three inches, Nantucket Island measuring an even three inches in 20 hours.

The western ridge, moving eastward during the next few days, brought sunny skies and increasing heat to the Rockies and Great Plains. Bismarck, North Dakota, reached 100° on the 6th, the peak of a series of high readings extending from the 3rd to the 9th, and no measurable rain fell there from the 1st to the 16th—a complete reversal from the rainy, cool conditions of May. As the ridge continued its eastward migration, the hot air overspread the Midwest and East—Chicago had 94° on the 8th, New York City 95° on the 9th, and finally Boston's protective east wind was routed to give a 96° reading on the 10th as the ridge line finally reached the Atlantic Coast.

After these opening preliminaries the major phase



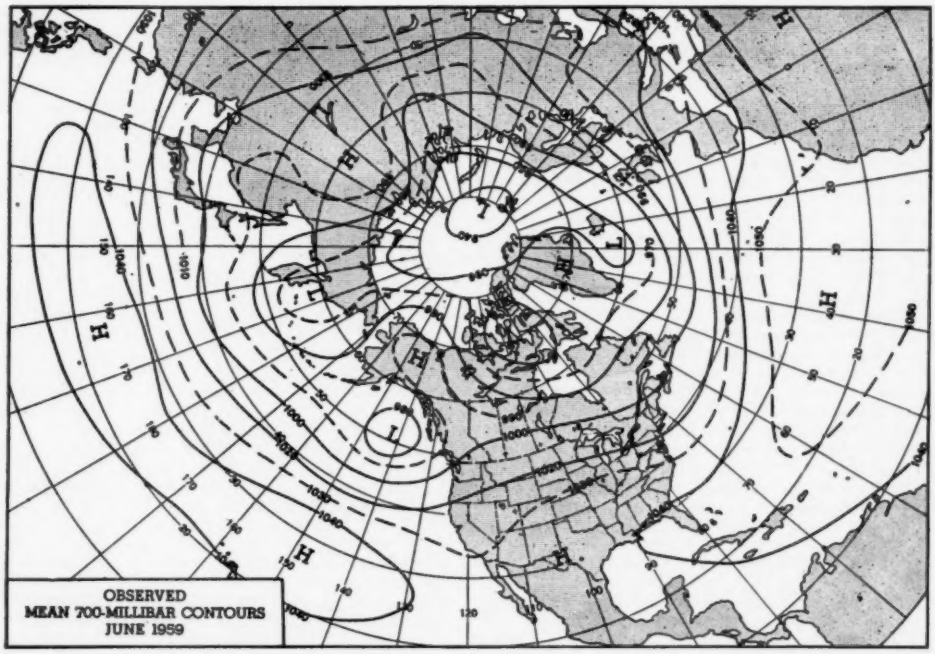
Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

of the month's weather opened. From the 11th to the 24th the weather map exhibited the same characteristics almost daily: a persistent ridge over the Plateau, Rocky Mountains, and western Great Plains in conjunction with an equally well-established trough along the Atlantic States. The western upper-air ridge maintained its backbone roughly along the 100° W meridian from western Dakotas to western Texas. Pressure departures aloft centered in a maximum over Wyoming and Utah. All of the West experienced a very warm period. In Arizona June averaged the warmest in 80 years of record. Yuma's figure of 92° topped the previous June highest by 1.3°. The mercury read above 100° on every day but one, the 27th, when the high mark reached only 98°! From the 11th to the 25th, the core of the hot spell, the daily maxima reached 109° or higher—the peak came on the 23rd with 116°. At Salt Lake City the string of 14 consecutive days from the 12th to the 25th with 90°-plus comprised the second longest such June stretch in airport records. The vast extent of the heat belt may be indicated by the existence of areas with a departure from normal of six degrees or more in Arizona and also in South Dakota, representing heat peaks in a hot zone which reached from the Great Lakes southwestward to the Pacific shores of southern California.

Readers who scanned the May upper-air charts will recall that a long looping trough extended from Hudson Bay southeastward, curving seaward around Newfoundland and then heading southward into the western Atlantic to pass near Bermuda. The same feature appeared on the June monthly mean charts; but now, having retrograded westward, was in a po-



sition to have a much more positive influence on the weather of the immediate Atlantic Coast. In June the trough occupied a mean position from Nova Scotia, just offshore along the Middle Atlantic Coast, to the northwestern Bahamas off Florida. Typical trough conditions with cloudy skies, frequent rainfall, and cool temperatures characterized the middle weeks of the month along the Atlantic seaboard. The Boston summary typified the doleful reports from coastal New England: "Excessive cloudiness, frequent rainfall, lack of sunshine, and an average temperature much below normal were characteristics of this not so pleasant month. It was the cloudiest June of record with only one clear day, the 30th. The month's total rainfall of 8.63 inches has been exceeded by only one other June in the past 87 years, 9.13 inches in 1931. Hail, up to ¾-inch in diameter, occurred in a thundershower on the 6th. Rain fell at an excessive rate on that date, and again on the 13th when an inch was recorded in a half hour." Atop Mt. Washington eight inches of snow fell from 14–18 June and other high peaks in northern New England wore a snow mantle.

The Atlantic Coast trough provided the locale for some interesting cyclonic gyrations as a low pressure circulation, blocked by a tenacious ridge over eastern Canada, remained over the Massachusetts Bay and Gulf of Maine area for a full week from the 13th to the 20th. Three different surface lows were drawn into this vortex, all performing complete 360° circles before resuming their normal northeasterly tracks. The most notable appeared in the passage of a tropical storm from the western Gulf of Mexico, across the peninsula of Florida, and northeastward in the Atlantic Ocean between Hatteras and Bermuda. Then it came under the influence of the blocking action in eastern Canada and recurved northward and then northwestward to smash into the Maritime Provinces of Canada with disasterous results.

After a period of almost two weeks of steady-state, the atmosphere underwent a final reshuffling for June. The strong western ridge again moved eastward as a trough from the Gulf of Alaska approached the Pacific Northwest with refreshing maritime air. With the arrival of the cold front, winds shifted into the northwest to end the memorable June heat wave over the West. Some precipitation fell over the long-dry areas of the Plateau and Rockies. At higher elevations in the Rockies the air cooled sufficiently to cause moderately heavy snowfall above 7,000 feet as your editor witnessed late on the afternoon of the 27th at the western entrance to the Moffat Tunnel in central Colorado.

Downstream from this activity the migrating ridge spread out over the Southeastern States and formed a juncture with the Bermuda High, a normal summertime position from which it could move tropical Gulf air masses northward. Temperatures and humidities soared from the Mississippi River eastward. No matter what index was consulted or what nomenclature was employed, it was just plain "miserable," the worst of the season so far. At Washington's National Airport, the mercury reached 99°, 100°, and 100° on the last three days of June—even the Weather Bureau's Office of Climatology, from whence sprang the discomfort index, checked their wet and dry bulbs, multiplied by 0.4, added 15, and went home at 1400 EDT.

The Gulf of Mexico area, the scene of considerable cyclonic activity in June, comprised a climatic zone of its own for most of June. In addition to tropical storms Arlene on 30 May–2 June and Beulah on 17–18 June, there were three other tropical disturbances in the Gulf of Mexico which did not achieve major circulations, though they greatly affected sky conditions across the Southern States. Pressures both at the surface and aloft averaged well below the seasonal normal along the Gulf Coast to cause much cloudiness and precipitation. Practically all areas of the South had below normal temperatures and above normal precipitation. The only places with below normal rainfall were northern Georgia and the Carolinas where May had been a very wet month. A strip across southern Florida from Miami to Ft. Myers had excessive June rainfall with tornado-plagued Miami reporting the greatest June total of record.

MIAMI TORNADO—The most severe tornado in Miami since 1925 occurred on 17 June. The funnel first touched ground in Cocoplum Plaza on the southwesterly tip of Coconut Grove (Coral Gables) at 2150 EDT. It moved northeastward about four miles and then lifted temporarily over the Miami business district. The funnel returned to the ground near N.E. 2nd Avenue and 43rd Street. The tornado moved into Biscayne Bay near 90th Street, continued northeastward across Biscayne Bay until reaching land again south of Sunny Isles, where the tornado went out to sea. Most all injuries sustained during storm were the result of cuts from flying and broken glass. The tornado moving at a speed of 25–30 mph and path width varied from near 350 yards at south end to about 60–75 yards at north end of track. Total storm damage estimated at near $3 million.

May (*Continued from page 169*)

contributed to an intensification of the entire system as pressure dropped rapidly at the center and a beautifully symetrical, oval-shaped circulation with closely packed isobars surrounded a 982 mb-29.00″ center. The depression remained in the vicinity of James Bay on the 12th and 13th before performing another southeastward loop to the vicinity of Montreal, then a northeastward reversal to pass up the St. Lawrence Valley and cross Labrador on the 14–17th. The accompanying upper-air trough also moved slowly eastward and by the 13th was along 85° W on the Cleveland-Atlanta axis. Upstream at this juncture the following ridge developed great strength as shown by the build-up of the surface anticyclone over the northern prairies of Canada to the unusual May pressure of 1044 mb-30.83″. With the ridge reaching to the very shores of the Arctic Ocean, the way was open for a great rush of frigid air southward into the central and eastern portions of the United States. Temperatures tumbled below the freezing mark on the 13–15th in the upper Mississippi Valley and on the 15–17th in the Northeast as the great May anticyclone dominated all.

The second phase of May's weather came to an end as the large anticyclone reached the Atlantic Coast on the 18th and merged with the extension of the Bermuda High, a union which reestablished ridge conditions over the area east of the Mississippi River. Once again the western trough-eastern ridge regime reestablished the broad southwesterly and southerly air streams over the Great Plains. For most of the concluding ten days of May a wide trough of great extent stretched from Hudson Bay southwestward to California and Oregon. The temperature

departure maps for the final two weeks of May readily show how the trough divided the country into two thermal compartments with the line of demarcation running from Minnesota to New Mexico, and this line also marked the area of heaviest precipitation as the conflicting air masses created turbulent atmospheric conditions almost daily. The strength of the Bermuda High gives the key to both the first and third phases of May's weather. Surface pressure just off the Carolina Coast averaged 3 mb above normal for the whole month, and upper-air charts reflect the same trend with the greatest departure from normal overlying West Virginia.

The position of the Bermuda High also explains the rainfall pattern over the Atlantic States during the final two weeks of May. Adequate rains fell over the Southeastern States as the easterly circulation around the southern periphery of the high permitted Atlantic and Gulf moisture to move northward; but in the Middle Atlantic and New England States, where air flow around the Bermuda High was mainly southwesterly off the continent, rainfall fell far below normal with some areas being rainless for a full week at a time. Philadelphia had its driest May since 1887.

MID-MAY FREEZE—The middle days of May often produce a cold snap capable of dropping temperatures slightly below the freezing mark over a large portion of the northern United States. This appears to be about the latest in the season that conditions can exist for the movement of a major anticyclone southeastward and still have it accompanied by an air mass with potential freezing temperatures. In the historical past New England experienced a much-lamented freeze on 18 May 1794 of sufficient economic importance to evoke a contemporary article in the Massachusetts Historical Society's publication. About once a decade snow storms are reported across northern New York and New England at this time. This condition has long been noted in Europe's weather as one of the season's singularities with the name Ice Saints employed for the days from 11 to 13 May. In our country the only name applied to this period comes from interior North Carolina where the term "dogwood winter" is used since the last hard frost often coincides with the blooming of the dogwood in mid-May.

The genesis of the 1959 mid-May freeze lay in the relationship between a deep, slow-moving low over Ontario on the 11–13th, and the upstream build-up of a strong polar anticyclone. Temperatures, which had been close to freezing over Montana from the 10th on, plunged further with the push of polar air southward on the 12th, dropping well below freezing over much of North Dakota and Minnesota on the morning of the 13th. Twenty-four hours later the frost had extended into Nebraska, and on the 15th into Kansas where Abilene registered 30°. Extreme readings were reached in the Dakotas with marks of 16° at Valley City, North Dakota, 19° in South Dakota, and 22° in Minnesota.

Frost occurred in the cranberry bogs of Wisconsin. In Michigan it was down to 21°, 28° in Ohio, 26° in New York, 30° in Pennsylvania, and well-below freezing in the highlands of New England. The extent of the cold is reflected in the 22° mark reached at Klingman's Peak in North Carolina, elevation 6250′.

RAINS ON THE PLAINS—An increasing drought situation over much of the Great Plains had become a serious threat to agricultural prospects at the close of April. Many northern sections suffered from five consecutive months with below normal precipitation, and in the Texas Panhandle July 1958 had been the last previous month with above normal rainfall amounts. The rains finally came during the opening days of May, almost in monsoon fashion, to nourish winter wheat crops at a critical stage of development, to insure good planting conditions for spring crops, and to turn ranges green once again. The observer at Sioux City, Iowa, summarized the situation: "May 1959 was unusually cloudy and wet. Topsoil and subsoil was well soaked by the end of the month; thus relieving a dry soil condition of several months duration. This was the wettest May at Sioux City in over 50 years, and the third wettest on record." A total of 8.46″ fell at Sioux City, 5.12″ above the normal. Amarillo, in the southern Plains where there had been a seven-months drought, had 1.70″ on May 4th and 2.19″ on the 7–8th to put the May total 1.81″ above normal. It was the same story elsewhere in the eastern Plains from Texas to Minnesota, though a few dry spots showed along the northwestern periphery of the Plains especially in eastern Montana and western North Dakota.

There were three periods of general rains. From the 2nd to the 10th rain in major quantities was reported on every day from some part of the area as slowly-moving fronts with good air mass contrasts triggered frequent showers and thunderstorms. A second period followed from the 17th to the 22nd as an east-west front across Missouri, Kansas, and Colorado lingered, and then took a northeast-southwest position to prolong the stormy period. The third phase of heavy rains came on the closing days of the month and concentrated on the Dakotas where rains were needed the most; but eastern Nebraska, eastern Kansas, western Iowa, and western Missouri received more than local streams and soil could handle with the result that floods swept several valleys. The Black River at Frankfort, Kansas, crested at a near record height. In Iowa, the Little Rock, Otter, Des Moines, Racoon, and Floyd rivers were all above flood stage; and in Missouri the Grand and Chariton rivers were high as a result of torrential cloud-bursts on the 30–31st.

As expected in summer rainfall situations, the distribution of precipitation was rather uneven. In Kansas, for instance, the monthly May totals ranged from 11.93″ to 0.84″—at Pleasant Hill a fall of 4.74″ occurred in 50 minutes. Lincoln, Nebraska, received a total of 8.91″ (5.81″ above normal) to make the January–May period the wettest in the local records which commenced in 1878.

The belt of excessive precipitation ran north-northeastward from west-central Texas to western Lake Superior along the path of May's main cyclonic activity. In the northwestern extremity of the Great Plains, Williston, North Dakota, had a measurement of only 0.78″ for the third dry month in a row; and to the east of the wet belt, Milwaukee, Wisconsin, caught only 1.28″ for the driest May since 1897. In general, however, most of the large grain-growing sections of the country in the great central valleys were well watered and looked forward to another bumper year of crops to compound the surplus problem.

CALIFORNIA DROUGHT—April, usually the last month of the rainy season, brought only one minor precipitation period to the State of California this year. On the 25–26th rains fell over all parts of the area with light to moderate amounts along

the coast and very light falls inland. This proved to be the last general rain for the state as a whole as cloudless day succeeded cloudless day during May and June. On 14 May most coastal points from San Francisco northward experienced their only measurable May rainfall—0.04″ at the Airport and 0.02″ downtown. The rains did not reach across the Bay as Oakland recorded only a trace during the month to make 1959 the driest May of record. Inland at Sacramento it was the same story as only a trace fell at the State Capital to tie the May record for least rainfall. There has never been a rainless May at Sacramento, but on only five other occasions has a trace been recorded, the most recent previous to 1959 being just 50 years ago. Traces were also recorded at Los Angeles and San Diego. These did little to check the record-approaching deficits for the 1958–59 rainfall season which runs annually from July 1st to June 30th.

June followed the example of May over all of California. Only a trace was recorded at downtown Los Angeles to bring the seasonal total to only 5.58″, the lowest figure in Weather Bureau records at the southern California city where tabulations commenced in 1877–78. The normal season rainfall is 14.54″—in 1957–58 a total of 21.13″ fell.

Thunderstorms

(*Continued from page 160*)

To get at this, we need some measure of "fairly well distributed in azimuth." A reasonable criterion might be that the observer has no storm-free quadrant. Since one quadrant of a circle of 25-mile encloses 490 square miles, any one observer-quadrant contains the fraction 0.049 of the total 10,000-square-mile model area. If we then imagine for the moment that no storms have appeared anywhere within the 10,000-square-mile area, the probability that the first of fifty randomly located storms to appear will *not* fall within any one quadrant of a given randomly located observer's circle of detectability is $1 - 0.049$ or 0.951; hence the probability that not a single one of fifty such randomly located storms will fall within that quadrant is 0.951 raised to the fiftieth power, or 0.08 approximately. Thus, for a very large sample of observers, probability theory predicts that only about 8 per cent of all observer-quadrants will be entirely storm-free in the present model. (By similar methods, one can show that less than 1 per cent of all observers will have two storm-free quadrants.) Thus, a very heavy majority of observers will, even with the sparse storm distribution considered here, have *at least* one storm in each quadrant of their circle of detectability. We may safely conclude that the encirclement illusion will be quite common among persons who are better observers than they are statisticians.

Finally, we may note that each shower area, specified to be a mile in diameter, covers only 0.79 square mile. All fifty storms then cover 39.4 square miles, or 0.39 per cent of the entire model area. Hence the probability that rain will actually be falling upon any randomly located observer is 0.0039, which is impressively low.

We may summarize these probability considerations by nothing that, if a meteorologist were to tour our 10,000-square-mile area immediately after outbreak of our fifty airmass thunderstorms and if he were to interview, say, 1,000 farmers, ranchers, or other observers interested enough to pay close attention to the storms occurring over the countryside, he must expect to find only about four observers upon whom rain had actually fallen; the other 996 would be intervewed on dry ground. Of these 996 disappointedly dry observers, some 920 could be expected to stress that they had seen showers in every one of their four quadrants. Clearly, then, such a meteorologist-interviewer would be overwhelmed by bitter assertions that "It rained everywhere but here"; so he should go prepared to explain how airmass meteorology and simple probability theory account for so many dashed hopes when convective showers appear in an area where rain is at a premium.

Ice Falls Data Requested

Editor:

Our Committee would appreciate any information, references and, particularly, conclusions that you may have concerning the phenomenon of "ice falls," i.e. large pieces of apparently natural ice, ranging in weight from approximately 10 pounds to possibly 150 pounds or more, that have reportedly fallen to earth for more than a century.

We realize that you are familiar with the Pennsylvania episode in which there were at least seven "falls" of ice in that state between July 30, 1957 and January 18, 1958.

Undoubtedly you possess accounts of other "falls" both preceding and subsequent to this period (such as those of March 1957 and 1958 in California and that of September 2, 1958 in Madison Township, N. J.).

The most recent reports we have in our records are for 1959 in California at Los Angeles, Glendora, and Atherton.

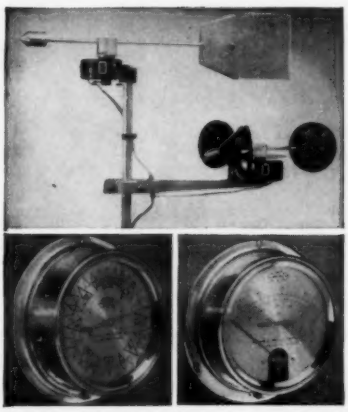
To the best of our knowledge this subject remains at present in the category of an unexplained phenomenon. In certain cases it may be correct to attribute such "falls" as being ice from aircraft or the misidentification of hailstones. It would seem, however, that a significant number of such cases cannot be so resolved considering their long history; the size of the ice chunks; the fact that many have fallen from a clear sky; and, if accurately reported, the particular structure and chemical nature of the examined pieces.

Specifically, we are interested in establishing a comprehensive record of such "falls" and in determining in so far as possible the structure, cleavage, crystallography, chemical make-up, and sediment content of such pieces of ice. In addition, we are also interested in obtaining some sample statistics concerning the forces necessary to maintain hailstones aloft and those required to contain pieces of ice of any given size within a jet stream.

In thus outlining our interests we are not so presumptuous as to expect a detailed, point for point reply but any information that you may find it convenient to provide, including reference to specific studies of your own or others, will be gratefully received.

RICHARD HALL,
Secretary, NICAP

Ed. note—The above letter was addressed to the American Meteorological Society by Richard Hall, Secretary, National Investigations Committee on Aerial Phenomena, 1536 Connecticut Avenue, N.W., Washington 6, D. C. The NICAP is a privately-supported fact-finding body serving the national public interest. Any reader who can shed any light on the subject of "ice falls" is urged to write Mr. Hall at the Washington address.



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Northumberland Strait Storm

(*Continued from page 162*)

tremely unusual event. Storms of this intensity appear to occur very rarely in the Maritimes in June and July. Past records show that over 43 years the maximum recorded wind at Halifax in these months was 35 mph. At Charlottetown and Summerside highest previous readings were 35 and 38 mph. But on June 20th at 0500 the anemometer at Summerside air port was reporting 55 mph with gusts to 70.

The loss of life from this storm was unusually large. Greater, no doubt, as the fishing boats had gone to sea earlier than usual to take advantage of a good salmon run. Without radios they could not receive the warnings and marine forecasts that during the evening of the 19th and later gave periodic advice on the intensity and movement of the storm. Research will provide new tools to forecasters, and continuing study by meteorologists will give greater knowledge and experience, but the once in a long time occurrence of a storm such as this will continue to challenge the best in meteorologists and their science.

Federal Weather Survey

The Federal Aviation Agency has awarded a $573,963 contract to the Borg Warner Corporation, Chicago, Illinois, for a two-year study of information needed to satisfy aviation weather services for the next 15 years. Information will be collected from some 140 installations such as commercial air carriers, the military, and general aviation organizations. The project will help to determine the type and amount of weather information required to cope with the increasing speed and complexity of air traffic.

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DR 87

Tower at Mount Washington

(*Continued from page 138*)

Methods of construction were carefully studied. Our consulting engineers, Cleverdon, Varney and Pike, of Boston, Mass., had considerable experience in the design of structures on the summit of Mount Washington, including the radio tower and the Climatic Laboratory. Analysis of the structural requirements was based upon their past experience with the area. With the circular shape of the Tower in mind, concrete was selected for the structure. The plastic qualities of this material make its use advantageous for this project.

Attached to the concrete structure is a light panel wall formed with vertical tongue-and-grooved wood as the exterior finish. This wood wall is braced from floor to floor with light steel members which are extended to withstand the force of the wind on the railing of the open deck. No special treatment is planned for the wood, since the present wooden tower and the existing hotel water tower show no signs of deterioration, yet have no special surface treatment.

All glazing for the public area and the laboratory will be insulating glass similar to Pittsburgh's Twindow, which is now used in the present Observatory building.

It should be carefully noted that much of the relatively high cost of the project (approximately $150,000), is directly due to the difficult working conditions and cost of transportation to the summit of Mt. Washington.

The foregoing description indicates a program by which the Mt. Washington Observatory can achieve a modern facility for its work, which will, at the same time, be integrated into the past traditions and the future development of the summit area.

The Mount Washington Observatory of Gorham, New Hampshire, is a Voluntary Corporation, organized under the laws of New Hampshire—"To make, summarize, and report scientific observations, chiefly geophysical, in the vicinity of Mount Washington, New Hampshire; to conduct research on subjects related to such observations; to conduct radio studies on Mount Washington; and to further public safety and public appreciation of scientific work on Mount Washington."

Membership in the Mount Washington Observatory is open to all with an interest in the above objectives. Dues are $1.00 per year and this includes a subscription to the interesting *News Bulletin*. Additional contributions to help defray the expenses of operating the Observatory are always welcomed. All communications should be addressed to Mr. Joseph B. Dodge, Mount Washington Observatory, North Conway, New Hampshire. Mr. Dodge is Treasurer and Managing Director of the Observatory.

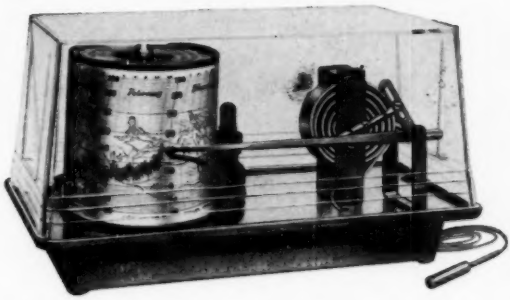
Dr. Wallace E. Howell, Bedford Airport, Bedford, Massachusetts, was recently elected president of the Observatory to succeed the late Dr. Charles F. Brooks, for many years the president and guiding spirit of the Observatory.

Respectfully submitted,
BASTILLE HALSEY ASSOCIATES.

Tentative Radar Installation Dates

Miami, Fla.	June 1959
Washington, D. C.	July 1959
New York, N. Y.	Aug. 1959
Brownsville, Tex.	Aug. 1959
Wilmington, N. C.	Aug. 1959
Kansas City, Mo.	Aug. 1959
Atlantic City, N. J.	Sept. 1959
Charleston, S. C.	Sept. 1959
Daytona Beach, Fla.	Sept. 1959
Apalachicola, Fla.	Sept. 1959
St. Louis, Mo.	Sept. 1959
Key West, Fla.	Oct. 1959
Tampa, Fla.	Oct. 1959
Des Moines, Iowa	Oct. 1959
Evansville, Ind.	Oct. 1959
Sacramento, Cal.	Oct. 1959
Buffalo, N. Y.	Nov. 1959
Cincinnati, Ohio	Nov. 1959
Amarillo, Texas	Nov. 1959
Oklahoma City, Okla.	Nov. 1959
Detroit, Mich.	Nov. 1959
Wichita, Kan.	Dec. 1959
Ft. Worth, Tex.	Dec. 1959
Little Rock, Ark.	Dec. 1959
Chicago, Ill.	Dec. 1959
Lake Charles, La.	Jan. 1960
New Orleans, La.	Jan. 1960
Houston, Texas	Feb. 1960
Charleston, W. Va.	April 1960
Minneapolis, Minn.	April 1960
Missoula, Mont.	May 1960

Low Cost Thermographs



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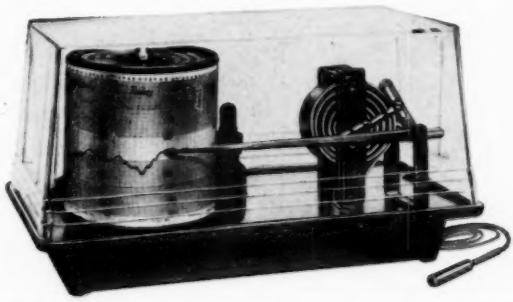

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